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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XIV.—*The Ventral Integument of Trilobites;* by C. E. Beecher. (With Plates II–V.)

In previous papers by the writer, on the structure and appendages of *Triarthrus*,[1-6] no attempt has been made to describe or illustrate the character of the ventral integument, especially in the sternal or axial region. The specimens hitherto described were prepared to show details of the appendages, and though portions of the ventral membrane were exposed in many individuals, the subject was not considered of sufficient moment to warrant a distinct study, particularly as no characters were observed in the cuticle that had not been previously seen in more or less perfection by Walcott[10] in the genera *Ceraurus* and *Calymmene*. A recent discovery by Jaekel,[8] however, necessitates the separate consideration of this structure. This necessity arises from the fact that a positive addition to the knowledge of the trilobite anatomy may be deduced, although, as will be shown, Jaekel was apparently entirely misled in his interpretation of the nature of his discovery.

In the paper under discussion, Jaekel[8] states that the occasion for his publication arose from the finding of a specimen of *Ptychoparia striata*, from the Cambrian of Bohemia, in which some structures were preserved in the axis of the six anterior segments of the thorax. These, he asserts, are the proximal joints of the legs.

The specimen was preserved as a cast in a rather coarse-grained sandstone, and is exposed from the dorsal side. From certain surface indications of lines in the cast, Jaekel was led to follow these into the rock filling the axis, and succeeded in

finding a central groove, with two oblique grooves on each side. These he considered as representing the cavities left by the removal of the test from the basal joints of the legs, which thus must have been attached along the median line of the sternum. The supposed joints of the legs were filled with rock, and his attempts to separate them from the matrix resulted in failure.

In the oral region, there were still more indefinite and obscure evidences of cavities left by the removal of some ventral testaceous structure.

These meager remains in the rachis of the thoracic and oral regions have furnished data for what must be considered as the most remarkable and erroneous reconstruction of the trilobite appendages and anatomy that has appeared since the time of Burmeister,[7] in 1843. The latter, in the absence of any material, confessedly based his opinions of the ventral anatomy wholly upon theoretical considerations. Not only has Jaekel to a large degree set aside the evidence presented by many scores of specimens of *Triarthrus*, as described by the writer, in which each detail of structure can be verified indefinitely, but has also overlooked that afforded by the material illustrated by Walcott,[10] Billings,[8] Mickleborough,[9] and Woodward.[12] Moreover, this single specimen of *Ptychoparia* has led its describer to reconsider on a false premise the entire question of the anatomy, ontogeny, phylogeny, and affinities of the trilobite.

It is the purpose of the present article to show that numerous individuals of *Triarthrus*, as well as some material representing other genera, preserve evidence of what seems to be the same structures as those described by Jaekel in *Ptychoparia*, and also present indisputable testimony as to their correct nature. It will be demonstrated that they do not belong in any way to the appendicular system of the trilobites, but are really the buttresses and apodemes of the ventral body integument.

The marvelous state of preservation of many of the specimens of *Triarthrus*, whose appendages have been studied by the writer, affords very satisfactory indications, not only of the presence of a ventral integument, but also of some of its detailed characters. Jaekel states that in his opinion the *unfavorable* ("*ungünstigen*") preservation of *Triarthrus* has obscured the proximal structure of the legs, so that what he calls the three basal joints are equivalent to the single unjointed gnathobase of the coxopodite, as described by the writer. Inasmuch as Jaekel has never seen the original specimens described, his statement is practically without foundation. It may also be added that the types and best-preserved individuals have been

retained in the collections of the Yale University Museum. The photographic illustrations accompanying this article, it is believed, will refute his statement, and the specimens themselves would serve the same purpose more completely, since from the black nature of the rock and the nonactinic character of the fossils the photographs feebly represent the delicate structures actually preserved, which are clearly visible to the eye.

The ventral membrane of *Triarthrus*, as well as of other trilobites where it has been observed, is of extreme tenuity and only under the most favorable conditions has it been preserved. The membrane itself was a thin, uncalcified, chitinous, flexible pellicle, and thus was in strong contrast with the much thicker and calcified dorsal test.

In the preparation of a specimen to show the appendages from the ventral side, very little of the ventral membrane is commonly exposed, owing to the crowded arrangement of the legs, but when the appendages are removed it is possible to view the entire ventral integument. This process has been carried out in a considerable number of specimens, and some of the more evident characters are herewith described.

The membrane under each pleuron (pleurotergite, Jaekel), or the pleurosternite, as it may be termed,* was smooth and extremely thin, and in the fossils it is invariably concave. This was probably the condition during life, to allow space for the biramous legs and for their infolding during enrollment. It should be noted, however, that the dorsal and ventral integuments in the fossils are generally very close together throughout, leaving but a small cavity for the soft parts of the animal. The space inside has doubtless been considerably reduced by partial collapse from the decay of the soft parts of the animal and also by the pressure of the sediments. The size of the body cavity is unquestionably more correctly shown in the specimens described by Walcott[10] and Mickleborough,[9] from the Trenton limestone and Cincinnati shales, respectively, where they have apparently suffered less compression.

Walcott showed that the membrane in *Calymmene* and *Ceraurus* was strengthened in each segment by a transverse arch, to which the appendages were attached at the sides of the axis. These arches were connected by a thinner membrane

* Jaekel has suggested the name mesotergite to supplant the terms axis or tergum, and pleurotergite in place of pleuron or epimerum, as applied to the trilobites. This seems a useful terminology since the older terms are often loosely used and have somewhat different meanings in other groups. Applying this system of nomenclature to the ventral integument, the writer would propose the terms *mesosternite* for the membrane beneath each mesotergite, and *pleurosternite* for the membrane beneath each pleurotergite. The interarticular membranes are not included.

(the interarticular membrane), and were aptly compared to the arches in the ventral integument of many of the decapods. Similar features are present in *Triarthrus*, as illustrated in Plate IV, figure 1, and Plate V, figures 2–4, where it is seen that the interarticular membrane (Plate V, fig. 4) in a normally extended individual is somewhat less than half the length of the arches. The chitinous integument of the arches, or mesosternites, as they may conveniently be called, is thickened along the borders, and appears to be slightly incurved on the posterior edge. The arches are further strengthened by a series of median and oblique longitudinal ridges, or buttresses, which are generally progressively more developed in passing anteriorly from the pygidium along the thorax to the neck segment of the cephalon.

The ventral arch of each segment has the following arrangement of these ridges: There is first a median ridge generally extending from the posterior border entirely across the plate, but sometimes becoming obsolescent near the anterior border. Then, on each side, there is an oblique ridge making an angle of about sixty degrees with the posterior edge and extending inward, but not meeting, the median ridge, thus enclosing a subtriangular space with the anterior apex truncated. Outside of these ridges but still within the axial region there is often a second pair of somewhat more oblique ridges, enclosing rhombic areas.

The ridges are clearly produced by a thickening of the ventral integument, and can be seen when viewed from the dorsal side of a specimen in which the dorsal test and filling of the body cavity have been removed. *They are thus partly or wholly of the nature of apodemes, or plates of chitin, which pass inward from the mesosternites and divide as well as support internal organs, and they are not, therefore, in any sense the proximal joints of legs.* Besides serving in this manner they were doubtless efficient in giving the necessary firmness to the ventral arches for the attachment of muscles.

Were these observations confined wholly to the specimens of *Triarthrus*, there might still be some chance of error, although it is believed that the evidence presented by this genus alone is quite sufficient. Additional data, however, will now be given, regarding other genera and families of trilobites, described independently by other authors, and with no intention of representing the detailed characters of the ventral arches. In the search for trilobite appendages by various investigators, the ventral membrane has naturally been of secondary consideration, and in the case of Jaekel's work was of no consideration whatever.

The earliest studies and illustrations of trilobites giving some evidence of the nature of the ventral membrane are those by Walcott on the genera *Calymmene* and *Ceraurus*. The limitations of the ventral body walls of the animal were clearly shown by a marked change in the color of the rock between the white calcite filling the body cavity and the dark limestone matrix. In figure 7, Plate V, after Walcott,[10] showing a transverse section of *Calymmene* in the thoracic region, it is seen that the membrane in the axis, or the mesosternite, is marked by four distinct lobes representing cross sections of longitudinal folds, and also that the legs are clearly attached at the sides. These folds can in no way be construed as proximal joints of legs. The gnathobases in *Calymmene* are given in sections, in figure 3, Plate III, of Walcott's paper, and of *Ceraurus*, in figure 2 of the same plate. During a recent visit at the Museum of Comparative Zoology, the writer examined many of the sections made by Walcott during his long and successful search for trilobite appendages. The structure shown in the figure here given (Plate V, fig. 7) was verified, and other sections were observed in which the folds were more pronounced, sometimes extending as thin laminæ into the body cavity, thus having the character of a normal apodeme.

The second instance to be noted, where the ventral membrane has previously been illustrated, is a specimen of *Asaphus megistus* Locke, first described by Mickleborough[9] from the Cincinnati shales in Ohio. In his figure, an outline of which is here reproduced (Plate V, fig. 5), there are shown a number of discontinuous longitudinal lines in the axis of the posterior thoracic region. Mr. Charles Schuchert has kindly examined the original specimen, now preserved in the United States National Museum, and writes that the longitudinal wrinkles in the axis are organic and not due to accident nor to tool marks. In the best-preserved series "there are five longitudinal ridges, a central one with two on each side." They appear in cross section as shown in the sketch furnished by Mr. Schuchert (Plate V, fig. 6).

The correct interpretation of this specimen, as illustrated by Mickleborough[9] and Walcott,[11] is: That the club-shaped bodies lying within the axis are the gnathobases attached at the sides of the axis; the curved members extending outward from the gnathobases are the endopodites; the longitudinal ridges in the ventral membrane between the inner ends of the gnathobases are the buttresses and apodemes of the mesosternites; the slender oblique rod-like bodies shown in the right pleural region in Walcott's figure are portions of the fringes of the exopodites.

The last specimen to be noted in this connection is the individual of *Ptychoparia striata*, already mentioned as described by Jaekel.[8] A reduced photographic reproduction of his figure (Plate V, fig. 1) is presented here for comparison with similar structures, as described in *Triarthrus*, *Calymmene*, *Ceraurus*, and *Asaphus*. From the data here deduced, it would seem obvious that the specimen shows the imprint of the ventral integument in the axial region, the dorsal test and filling of the body cavity having been removed. As in *Triarthrus*, the body has suffered collapse, thus bringing the dorsal and ventral walls quite near together. In the middle of each of the five or six anterior ventral arches is a groove left by the solution of the chitinous median apodeme, or buttress. On either side are two oblique grooves limiting two subangular areas, and outside of these are two other oblique grooves marking off subrhombic areas. The grooves in each case represent the cavities left by the removal of the chitinous thickenings of the membrane of the trilobite. Jaekel's attempt to remove the rock filling these areas naturally was ineffectual, since the latter represent the actual impression of the ventral integument. Were they simply the fillings of the hollow leg joints, as he claims, they should be readily detached from the matrix.

The foregoing descriptions and discussions of the character of the ventral integument in trilobites would have little or no scientific value, and would be about as useless as a minute analysis of the nodes and tubercles on the glabella of a *Phacops*, were it not for the fact that from them it is possible to reach some conclusions regarding the musculature of trilobites, and thus add something to the knowledge of their internal organization.

In the abdomen of a normal crustacean, as is well known, there is a pair of longitudinal dorsal muscles, the *extensors* of the abdomen. They divide into bundles, which are attached on the inner surfaces of the tergites of the somites. Likewise, on the ventral side, there is a larger pair of longitudinal muscles, the *flexors* of the abdomen, from which strands are given off and attached to each sternal arch. The strands from one somite unite with the main bundles within the cavity of the next anterior somite. In a diagrammatic form, this disposition of the ventral muscles is represented in the accompanying figure (fig. 1).

Now, since in crustacea it is of very common occurrence to have chitinous extensions of the integument within the body cavity either to divide or to support organs, as well as for the attachment of muscles, it seems a necessary conclusion to refer the thickenings and buttresses on the ventral membrane of trilobites to the same class of structures, which are usually

termed apodemes. With this interpretation, the median longitudinal ridge on the mesosternite of a trilobite would indicate the line of division between the two main ventral bundles. The first pair of oblique ridges on each side would delimit the main bundles and side strands, and show that these strands joined the main bundles obliquely within the cavity of the next anterior somite, as in ordinary crustacea. This accounts for the anterior truncation of the triangular area between the median and lateral ridges in the trilobite.

The nature of the outside pair of oblique ridges is not so plain. They may serve to divide the side ventral strands of the flexors from the bundle of muscles running from the proximal joints of the legs to the dorsal test, or they may simply mark the outside of the lateral strands.

1

FIGURE 1.—Diagram of the axial portions of three segments; showing the ventral abdominal muscles, the flexors, represented as two heavy longitudinal lines, together with the lateral strands attached to the sternal plate in each somite and continuing obliquely forward to their union with the main bundle in the cavity of the next anterior somite.

The apodemes in general seem more strongly developed anteriorly in the thorax. Possibly, this condition may be explained on the basis that the ventral pair of the great flexor muscles received new strands at each segment from behind forward, so that near the cephalon they became large bundles for which progressively larger apodemes were formed.

It may be remarked, in conclusion, that a similar though apparently much simpler apodemal arrangement would be developed if the musculature of the trilobites agreed with that of the theoretical crustacean ancestor, or that existing in some Isopods, Amphipods, etc., in which there are no large longitudinal bundles, but motion between the somites is effected by strands running from one segment to the next anterior. If viewed in this manner, there would necessarily be two median and two lateral strands. The previous explanation seems to be more in accordance with the structures actually seen in the trilobites, which in general possessed the power of enrollment to a high degree, and would be expected to have had a well-developed and efficient system of ventral muscles.

Summary.—The ventral integument in trilobites is a thin uncalcified membrane, which may be divided into pleurosternites and mesosternites, corresponding to the mesotergites and pleurotergites of the dorsal test, and like them connected segmentally by an interarticular membrane.

The mesosternites are usually marked by five longitudinal ridges, or buttresses, representing thickenings of the membrane, which may be homologized with apodemal structures in other crustacea, and not with the appendicular system.

These buttresses, or apodemes, include a single median one for each mesosternite, with two others on each side extending forward and obliquely inward, and enclosing subtriangular or rhombic spaces.

The presence and disposition of these buttresses apparently afford information regarding the ventral musculature of the trilobites. A pair of flexors is indicated, together with the lateral strands attached to each mesosternite and extending forward and inward to their union with the main bundles within the cavity of the next anterior somite.

Yale University Museum, New Haven, Conn., January 24th, 1902.

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EXPLANATION OF PLATES.

PLATE II.

Triarthrus Becki Green.

FIGURE 1.—A specimen viewed from the dorsal side; showing the extent of the antennules and the limbs on the right side. Enlarged about three diameters.

FIGURE 2.—The ventral side of a pygidium; showing at the left of the median line the form and disposition of the exopodites and endopodites. The conical ends of the joints of the endopodites are provided with bundles of stiff hairs. Owing to the concavity of the specimen, it is impossible to show it all in proper focus. Enlarged ten diameters.

FIGURE 3.—The posterior portion of an individual viewed from the ventral side; showing the distal ends of the exopodites, with their setæ and long fringes. Enlarged nearly ten diameters.

FIGURE 4.—Dorsal view of an individual; showing the nine pairs of anterior thoracic limbs fully extended on the left side. The jointed endopodites and fringed exopodites may be clearly differentiated. Enlarged about three diameters.

FIGURE 5.—A still further enlargement of some of the limbs of the preceding specimen; showing in more detail the distinctive characters and arrangement of the exopodites and endopodites. Enlarged about ten diameters.

Utica slate, Ordovician, near Rome, New York.

This plate of illustrations, although very inadequately representing the actual objects, is introduced mainly to show the exquisite character of preservation of the specimens of *Triarthrus*.

PLATE III.

Triarthrus Becki Green.

FIGURE 1.—Ventral view of an individual; showing the basal joints of the antennules, the biramous appendages, and the series of gnathobases. The appendages within the cephalon indicate their biramous structure like those over the thorax. They are therefore not simple as restored by Jaekel. The anal opening is shown near the extremity of the pygidium, but is obscure on account of not being in focus. Enlarged three and one-half diameters. (Original of figure 1, Plate IV, vol. xv, American Geologist, 1895.)

Utica slate, Ordovician, near Rome, New York.

PLATE IV.

Triarthrus Becki Green.

FIGURE 1.—The ventral side of an individual prepared to show the character of the endopodites of the entire thoracic series. The gnathobases are distinctly seen extending obliquely inward from the sides of the axis; then follow, within the pleurosternal region, the subtriangular joints of the endopodites with more slender distal joints. The origin and course of the antennules at the sides of the hypostoma are also shown. In the middle of the axis of the mid-thoracic region, the ventral membrane is exposed, and the transverse limitations of the sternal arches and interarticular membrane may be observed. The arches show the buttresses or ridges of apodemal nature, as described in the text. Enlarged three and one-half diameters.

Utica slate, Ordovician, near Rome, New York.

PLATE V.

FIGURE 1.—*Ptychoparia striata* Emmr. *Dorsal* view of the anterior portion of a specimen preserved as a cast in sandstone, and enlarged about two diameters. In the glabellar and anterior thoracic region, the filling of the body cavity has been removed from the axial region, thus exposing the imprint of the hypostoma and ventral integument with its buttresses, or apodemal structures. Reduced from the original figure published by Jaekel.
Cambrian, Bohemia.

FIGURE 2.—A specimen of *Triarthrus Becki* Green; viewed from the *ventral* side. The appendages have been removed and the ventral membrane exposed. In the glabellar region are seen the hypostoma and just below it the semicircular convex metastoma with side lappets. Below, in the axial region, the buttresses and thickenings of the sternal arches are clearly marked, as described in the text. Enlarged about nine diameters.

FIGURE 3.—The same specimen enlarged only a little more than three diameters. The illumination is from the side opposite to that in the preceding figure.

FIGURE 4.—*Triarthrus Becki* Green. The ventral side of the middle thoracic region of the specimen illustrated on Plate IV; showing the ends of the pleurotergites on the outside, with the joints of the endopodites within the pleural regions, and the gnathobases extending obliquely inward in the axis. The sternal arches with their longitudinal ridges and the interarticular membranes are represented. Enlarged four and one-fourth diameters. The extensions of the limbs beyond the carapace are omitted.

FIGURE 5.—*Asaphus megistus* Locke. A reduced outline of the figure published by Mickleborough;[9] showing the endopodites in the pleural areas, with the gnathobases extending obliquely inward from the sides of the axis, and in the posterior thoracic median line the ridges or folds of the ventral integument. One-half natural size.

FIGURE 6.—An enlarged profile of the mesosternal ridges of the preceding; from a sketch furnished the writer by Schuchert. The lower represents the ventral aspect.

FIGURE 7.—Transverse section through the thoracic region of *Calymmene senaria* Conrad; after Walcott; to show the folds of the ventral integument and the basal joints of the legs, with their points of attachment at the sides of the sternal arch. Enlarged three diameters.

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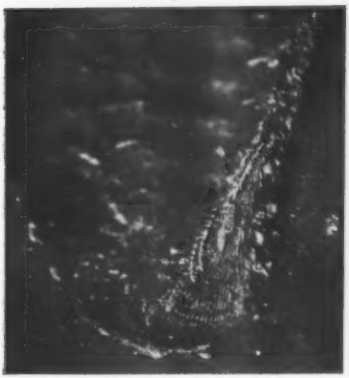

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Appendages of Triarthrus.

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Ventral side of Triarthrus.

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Ventral side of Triarthrus.

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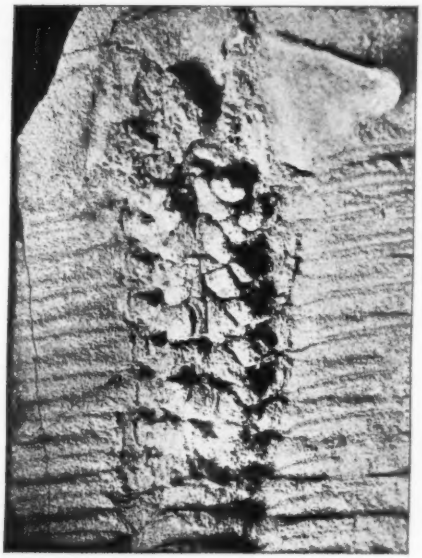

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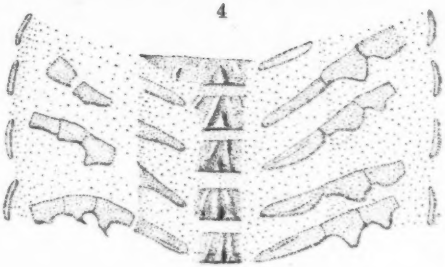

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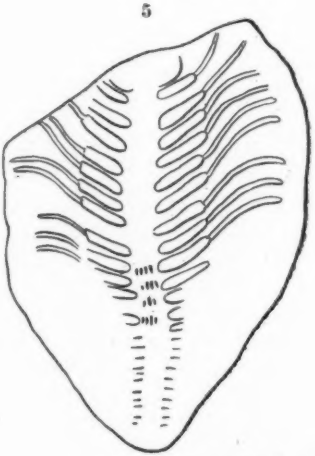

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Ventral integument of Trilobites.

Art. XV. — *Igneous Rocks from Eastern Siberia;* by Henry S. Washington.

The rocks which form the subject of the present paper were collected near East Cape in Siberia, during the summer of 1900, by Mr. A. G. Maddren, who, through the kind offices of Dr. L. B. Bishop of New Haven, generously sent them to me for investigation. It is a pleasure to record my thanks to both these gentlemen for the interesting material thus made available for study, and which has added another to the growing list of localities of foyaite and related alkalic rocks.

East Cape.

Foyaite.—The most interesting rock of the suite is one—the only one—from a locality given as "South of Whalen or Itschan, East Cape." As the locality is little known, it may be of interest to quote from a letter received from Mr. Maddren.

"The region in the vicinity of East Cape is a rugged one. Mountainous ridges of crystalline rocks come out to the seashore and form bold, rugged cliffs five to eight hundred feet in height. Between these ridges are low swampy stretches of tundra, with pebble beaches. The tops of the ridges are almost barren of vegetation, and the surface is overstrewn with frost-broken blocks of the country rock of all sizes and shapes."

The rock is quite coarse in grain, composed very largely of an alkalic feldspar, with less nephelite of a slightly brownish color. Scattered through these are small (up to 5^{mm}), stout prisms of hornblende, the arrangement of which suggests a schistose structure. Minute specks of purple fluorite are also visible with a lens.

Under the microscope the feldspar is seen to be distinctly tabular, in stout individuals, generally twinned according to the Carlsbad law. They show little, if any, microperthitic development, or the moirée appearance so characteristic of soda-rich orthoclase, and it may be inferred that the feldspar is nearly pure orthoclase. The nephelite occurs in stout individuals, xenomorphic toward the feldspar tables.

Interstitial between these feldspars and nephelite areas, but varying much in relative amount in different parts of the sections, is a finely granular, colorless substance, of low refractive index, the irregular grains, between crossed nicols, being either isotropic or showing yellow or orange colors of the second order, and optically positive. This mineral cannot be cancri-

nite, as was thought at first, since this is optically negative, and the small amount of CO_2 shown by the analysis corresponds to only 0·8 per cent of this mineral. As the analysis also shows an excess of alumina, the granular material must be regarded as hydronephelite, especially as the appearance of the aggregate agrees with the description by Diller of the hydronephelite of Litchfield, Maine.*

The hornblende, which is seen only rarely in the sections, is of a dark olive-green, with very intense pleochroism. There is also present, in less amount, a highly pleochroic, yellowish-green biotite, in stout ragged individuals, which resembles that of the Maine Litchfieldite described by Bayley.†

The small grains of fluorite are seen here and there in the sections, the purple color being often intense and again very faint. They are usually xenomorphic toward crystal faces of the feldspars, almost never as inclusions in the latter. Small zircons are fairly abundant, for such an accessory constituent, and a few titanites were seen. One of these last includes a minute, colorless, isotropic, well-shaped octahedron, of high refractive index, the nature of which could not be ascertained.

	I.	II.	III.	Ia.
SiO_2	55·38	53·56	55·87	·923
Al_2O_3	23·74	24·43	21·82	·233
Fe_2O_3	0·63	2·19	2·34	·004
FeO	1·26	1·22	1·10	·018
MgO	0·81	0·31	0·48	·020
CaO	0·67	1·24	3·07	·012
Na_2O	5·29	6·48	4·81	·085
K_2O	10·05	9·50	10·49	·107
H_2O 110°+	1·12	0·93	0·34	
H_2O 110°—	0·38	----	----	
CO_2	0·05	----	----	
TiO_2	trace	----	----	
ZrO_2	0·06	----	----	
P_2O_5	0·06	----	----	
SO_3	0·07	----	----	
Cl	trace	----	----	
MnO	trace	0·10	trace	
BaO	----	----	----	
	99·57	99·96	100·32	

I. Foyaite, East Cape, Siberia. H. S. Washington anal.

II. Nephelite-syenite. Beemerville, N. J. L. G. Eakins anal. J. P. Iddings, Bull. 150, U. S. G. S., p. 211, 1898.

III. Leucite-phonolite. Lake Bracciano, Italy. H. S. Washington anal. Jour. Geol., vol. v, p. 49, 1897.

Ia. Molecular ratios of I.

* J. S. Diller, this Journal, vol. xxxi, p. 266, 1886.

† W. S. Bayley, Bull. Geol. Soc. Amer., vol. iii, p. 236, 1892.

As the analysis showed an excess of alumina amounting to three per cent, it was thought possible that corundum might be present. The rock powder was accordingly digested with hydrofluoric acid and the residue examined. None of this mineral was found, however, the only substances unattacked being fluorite (whose identity was thus surely established), zircon, and a little of the hornblende.

An analysis of this rock yielded the results given in I, in the other columns being given analyses of rocks of similar chemical composition from other localities.

It is seen that this foyaite differs decidedly from nearly all others in the ratio of $K_2O : Na_2O$, this being close to unity, while in most of these rocks the soda predominates over potash to a very considerable extent, i. e. over 1·5 : 1. Indeed, the Beemerville rock, whose analysis is given above, is almost the only one of this group which approaches the Siberian in this respect.

The close similarity of the Italian leucite-phonolite, which differs only in slightly higher ferric oxide and lime, is very interesting, as another example to be added to the rapidly increasing list of rocks which, with similar chemical composition, differ radically mineralogically. The difference here is of course to be connected with the difference in geological occurrence; the Siberian and New Jersey rocks being intrusive, while the Italian is a surface flow. This tendency of leucite to form in extrusive rocks, while it is absent in intrusives of the same chemical composition, is a well known fact, but the present case is so well marked, and the similarity in chemical composition so great, that it seems worth while calling attention to it.

As to the mineral composition, if the attempt be made to calculate hydronephelite using the extra alumina as a basis, we get 24·1 per cent of this, 4·7 of albite and only 4·5 of nephelite. This result does not correspond with the appearance in thin section, which calls for much more nephelite. I have, therefore, calculated the rock as free from hydronephelite, which is an alteration product, the excess of alumina remaining uncombined. As has been pointed out elsewhere, this is a marked feature of other rocks belonging to the foyaite group* The result is given in I*a* below, the composition of the Bracciano leucite-phonolite being given in III*a*.

The albite molecule in I*a* is higher than the appearance of the orthoclase would indicate, as has been said above. It must be noted, however, that the hydronephelite present would reduce the amount of this considerably, as already seen.

* H. S. Washington, Jour. Geol., vol. ix, p. 609, 1901.

	Ia.		IIIa.
Orthoclase	55·5	Orthoclase	47·4
Albite	12·5	Anorthite	9·0
Nephelite	20·3	Leucite	12·7
Extra alumina	3·0	Nephelite	18·0
Hornblende	5·2	Aegirite	6·9
Biotite	3·4	Augite	6·0
Zircon	0·1		
	100·0		100·0

The calculation of III*a* is somewhat arbitrary, and is based on the assumption that all the soda, above that required for aegirite, goes into the nephelite molecule. Presumably some of it is in the feldspar, as albite, which would increase the actual amount of leucite. Judging from the sections this is very probably the case, but the relative quantities in each are quite unknown, so the simplest assumption is made above. The anorthite undoubtedly exists in the fine-grained groundmass, as its occurrence with orthoclase is a prominent feature of the Italian volcanic rocks. It is, however, difficult to detect it, and the augite may be somewhat more calciferous than the usual run of Italian augites, i. e. richer in the diopside molecule. Its amount as calculated is also increased by the assumption, made as usual, that all the Fe_2O_3 is in acmite.

In both cases the quantities of dark minerals calculated correspond well with the appearance in thin section.

From a general point of view this occurrence of foyaite is of interest, since heretofore these rocks have been observed in Siberia, and indeed in Asia outside of India, only at the Ilmen Mountains (Miask) in the extreme western part, this occurrence being long known. Recently another locality has been described by Morozewitch,* at Marinpol, Gov. Ekaterinoslav, in southern Russia, which may possibly, indeed probably, belong to the same general petrographical province.

The foyaites of Miask differ from that of East Cape in being in general richer in soda and poorer in potash, resembling in this respect the normal types. Analyses of them are given in the Guide to the Excursions of the VIIth International Congress (No. V, A. Karpinsky, p. 22, 1897), but as the analyses differ much among themselves, and are apparently not very reliable, it seems scarcely worth while to quote them.

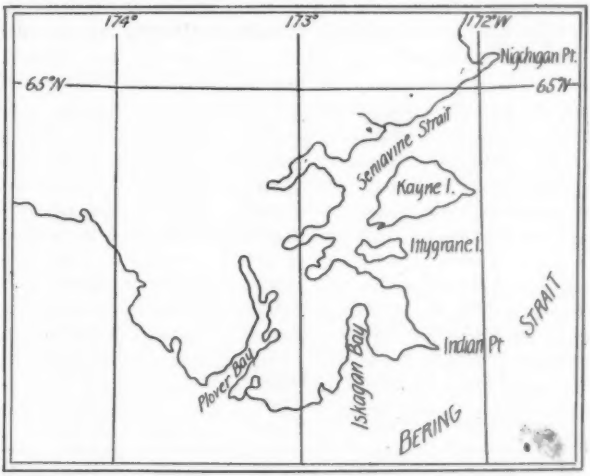
The Marinpol nephelite-syenites are still higher in soda, one of them giving a ratio of $K_2O : Na_2O = 1 : 24$, though it is not stated in the reference whether this is molecular or not, nor is the analysis given. It may be mentioned that to this pre-

* J. A. Morozewitch, Ref. in Neues Jahrb. Centralblatt, 1901, p. 727.

dominantly albite-nephelite rock Morozewitch gives the name of "marinpolite."

Iskagan Bay.

All the other Siberian rocks which were sent me by Mr. Maddren come from "the head of Iskagan Bay," a small inlet in lat. 64° 30′ N. and long. 172° 40′ W., about 230^{km} southwest of East Cape. The locality is shown on the accompanying map, copied from that of Alaska of the U. S. C. and G. Survey, for the drawing of which I am indebted to Mr. H. H. Robinson.



The character of the locality resembles the other, for Mr. Maddren says of it: "The Iskagan region is a very rugged and mountainous one, the shores of the bay rising up abruptly to snow-covered peaks." The specimens were collected from the talus slopes.

With one exception these rocks represent lava flows, or at least fine-grained porphyritic forms. It is, of course, impossible to say anything of their age, in the total absence of geological data, but from the partial devitrification of some of them and their general appearance, it is probable that they are not very recent.

Comendite.—The most interesting of these specimens is dense and compact, with a tendency to platy parting under the hammer, of a general flesh tint, sprinkled with dull greenish specks.

In thin section the rock is seen to be holocrystalline, composed almost entirely of irregular quartzes and orthoclase grains, the latter showing a tendency to automorphic development as stout prisms. A micropegmatitic intergrowth of the two is quite common. The feldspar is uniformly clouded with a brownish ferritic dust which gives rise to the megascopic color. Scattered through the mass are irregular shreds of a dark green aegirite-augite, with magnetite grains here and there. Neither zircon nor apatite was seen.

The crystallization of the $NaFeSi_2O_6$ molecule as acmite rather than riebeckite, in such siliceous rocks, is of comparatively rare occurrence, as noted by Pirsson in describing the apparently analogous aegirite-granite-porphyry of the Judith Mountains, Montana.*

	I.	II.	III.	IV.	V.	VI.
SiO_2	75·44	76·49	74·76	74·35	69·91	68·95
Al_2O_3	11·98	11·89	11·60	8·73	13·76	14·00
Fe_2O_3	0·88	1·16	3·50	5·84	2·17	2·12
FeO	1·02	1·56	0·19	1·00	1·23	3·56
MgO	0·10	trace	0·18	0·07	0·46	0·07
CaO	0·33	0·14	0·07	0·45	1·39	0·23
Na_2O	4·06	4·03	4·35	4·51	4·45	5·45
K_2O	5·01	5·00	4·92	3·96	6·33	5·29
H_2O+	0·68	0·38	0·64	0·25	0·12	0·05
H_2O-	0·13	0·12	----	----	none	----
CO_2	none	----	----	----	none	----
TiO_2	trace	trace	trace	----	0·16	0·35
P_2O_5	----	----	trace	----	0·11	----
MnO	trace	trace	trace	0·22	trace	0·55
	99·63	100·77	100·21	99·38	100·09	100·62

I. Comendite. Iskagan Bay, Siberia. H. S. Washington anal.

II. Paisanite. Magnolia, Mass. H. S. Washington anal. Jour. Geol., vol. vii, p. 113, 1899.

III. Comendite. San Pietro, Sardinia. M. Dittrich anal. Rosenbusch. Elemente, p. 237, 1898.

IV. Grorudite. Varingskollen, Norway. Särnström anal. Brögger, Eruptivgesteine Christianiagebietes, i, p. 48, 1894.

V. Aegirite-granite. Miask, Ural Mts. H. S. Washington anal.

VI. Arfvedsonite-grorudite. Frön, Norway. V. Schmelck anal. Brögger, op. cit., i, p. 139, 1894.

A chemical analysis of this Iskagan Bay rock is given in I above, with a few of the very many analyses which might have been chosen for comparison, in II, III and IV. It is

* L. V. Pirsson, Eighteenth Ann. Rep. U. S. G. S., Pt. III, p. 559, 1898.

remarkably close to the paisanite of Magnolia, Mass., but, as the dark mineral here is riebeckite and not acmite, the Siberian rock cannot be called by this name,—an instance of the undue importance attaching to comparatively trivial characters in the present system of classification.

It also resembles the comendite of Sardinia, differing from this notably only in the absolute and relative amounts of the iron oxides. In all three, it will be noted, the ratios (molecular) of the two alkalies are very close to unity. From the most siliceous of Brögger's grorudites (IV) it differs not only in this respect, for in the Norwegian rock the soda greatly preponderates over the potash, but also in the much higher ferric oxide and lower alumina of the latter.

It is true that comendite is placed by Rosenbusch among the effusive rocks,* as the equivalent of the hypabyssal paisanites, and that we have here no exact knowledge of the geological occurrence of the rock in question. Leaving this point aside, it would seem proper to call our rock a comendite, since the development of aegirite rather that paisanite is characteristic of this, and also because the Siberian specimen resembles a specimen of the Sardinian comendite kindly sent me by Signor Bertolio.

The mineral compositions of the Siberian and Sardinian comendites are given in I*a* and III*a* below, and are seen to differ only in the relatively greater amount of aegirite as compared with augite in the latter. The two are not calculated to 100 per cent, and the difference from the totals of the analyses are accounted for by the H_2O, etc., of these.

	I*a*.		III*a*.
Quartz	31·9	Quartz	31·6
Orthoclase	30·0	Orthoclase	28·9
Albite	33·0	Albite	32·0
Acmite	0·9	Acmite	4·2
Augite	2·1	Hyperstene	0·5
Magnetite	0·9	Magnetite and hematite	2·5

Recently aegirite-granites from Miask have been described by Pirsson† and Johnsen,‡ and, as it was thought that a chemical comparison of these with the comendite of Iskagan Bay might be of interest, an analysis was made of the Miask granite. The material for this was very generously given me by Prof. Pirsson, from the specimen already described by him, and I take this opportunity to tender my hearty thanks for his

* Rosenbusch, Elemente, p. 268, 1901.
† L. V. Pirsson, this Journal, vol. ix, p. 199, 1901.
‡ A. Johnsen, Neues Jahrb., 1901, II, p. 117.

kindness. The results are given in V above, with the analysis of a Norwegian grorudite in VI for comparison.

The Miask rock resembles that of Iskagan Bay, especially in the ratio of the alkalies, though these are here absolutely a little higher, as is to be expected, in view of the somewhat lower silica. Ferric oxide and lime are also present in somewhat greater amount, as is also alumina, but the two do not differ in any radical respect, except in the purely physical one of size of grain.

It is of interest to note that the relation of the Miask granite to the Frön grorudite is just about the same as was that between the Iskagan comendite and the Varingskollen grorudite, especially in the respective alkali ratios.

Quartz-porphyry.—A rock which resembles the preceding is represented by a slightly worn beach pebble. It is very fine-grained and porphyritic, the groundmass composed of alkali-feldspar and quartz, with phenocrysts of the latter mineral visible. The general color is a light yellowish brown.

The microscope shows that it is composed very largely of a fine-grained, holocrystalline groundmass of alkali-feldspar and quartz in almost equal amounts, with very rare specks of magnetite. Phenocrysts of quartz and of a somewhat microperthitic feldspar, often in Carlsbad twins, are scattered through this. The groundmass is highly micropegmatitic, and closely resembles on a smaller scale the granite-porphyry of the Castle Mountains.*

It was not thought worth while to make a chemical analysis of this rock, but from the microscopical examination it is evident that it is considerably richer in silica than the preceding one, and that probably the potash and soda are present in about equal amounts (molecularly). It may, therefore, be held to belong to the same series as the comendite.

Rhyolite.—A magma of a distinctly less siliceous character is represented by a specimen of a very dense, dark gray rock, sprinkled with many small phenocrysts of white orthoclase and rare ones of quartz. In general appearance it much resembles the old rhyolites of Massachusetts and other eastern states.

Under the microscope it is seen to be far from fresh, composed very largely of alkalic feldspar in irregular grains and small phenocrysts, a few of which show twinning lamellae, with extinction angles which correspond to albite or an acid oligoclase. A few irregular quartz grains are scattered throughout, but the total amount of this mineral is very small. There are also shreds and specks of a black substance representing an original ferromagnesian mineral, but this can have been pres-

* L. V. Pirsson, Bull. 139, U. S. G. S., p. 86, 1896.

ent only to a limited extent. There may have been glass in the rock originally, but, if so, devitrification has obscured it.

As no analysis was made of this rock its exact relationships cannot be discussed. It is evident, however, that it is rather more siliceous than the trachytes proper, and probably occupies in this respect a position intermediate between them and the rhyolites. The character of the feldspars indicates that it is decidedly alkalic, and with potash and soda probably in about equal amount.

Obsidian.—Three of the specimens are of flow rocks, highly glassy in character, but much devitrified, and offering little of interest.

One of these is purplish gray, with small yellowish spots and chains of what megascopically look like spherulites, but which the microscope shows to be at present, in great part, irregular quartz grains. A few are still true spherulites, and it is probable that they were all so originally. The groundmass, which was formerly glassy, is now thoroughly devitrified to a cryptocrystalline aggregate, apparently of feldspar with subordinate quartz. Ferromagnesian minerals are practically absent.

Another is a glassy breccia, much decomposed, of a general reddish brown color. Irregular fragments of a feldspathic rock, sometimes itself glassy, and often carrying aegirite, are cemented by a ferritic glass, which shows well marked flow structure.

The third is a dense black rock, almost wholly composed of devitrified and dusty glass, with fragments of quartz and of alkali-feldspar.

Monzonite.—The last rock to be described differs so much in a chemical and mineralogical way from all the others that it is highly probable that it belongs to a distinct rock series, though it also comes from Iskagan Bay. It is also the only one which was almost certainly of intrusive character.

It is of medium grain and granitic texture, composed of very white feldspar, with a little quartz, and quite abundant stout prisms and anhedra of black hornblende, though the amount of this is very much less than that of the other minerals, probably constituting from 20 to 25 per cent. of the whole.

In thin section the feldspar is seen to predominate very largely over all the other constituents, and to belong to two species. One of these is a finely striated plagioclase in partly automorphic individuals, which Lévy's method shows to be a labradorite of the composition Ab_3An_1. Along with this, but xenomorphically developed as interstitial masses, is an alkali-feldspar which, judging from the optical characters, is a predominantly potassic orthoclase. Some of this latter is cloudy

through incipient decomposition. Quartz occurs in anhedra, but its total amount is very small. It carries minute liquid inclusions.

The hornblende is olive-green, and shows the usual characters of this mineral in the dioritic rocks. It is occasionally epidotisized, and some actinolite is also present, derived apparently from the normal hornblende. There are also a few grains of magnetite, which are occasionally, when embedded in orthoclase, surrounded by a zone of biotite. Some grains of titanite are also present.

Although no analysis was made of this rock, yet its systematic position is quite clear. It obviously belongs to the monzonites of Brögger, and indeed much resembles type specimens of this from Predazzo, being slightly finer in grain. The amount of quartz is also a little greater, and the Siberian rock may possibly belong to the banatites or quartz-monzonites.

Locust, N. J., December, 1901.

Art. XVI.—*A Cosmic Cycle;* by Frank W. Very.

[Concluded from page 114.]

Concluding Stages of Stellar Growth.

I have referred the gradual diminution of hydrogen after the Sirian stage to its being used up in the formation of planets and comets. To this cause is adjoined in the stars of Secchi's fourth type, the attainment of a temperature so low that hydrogen and carbon combine, whereby the last traces of hydrogen are removed. Previously to this, however, come bright-line variable stars of banded type, where either the evolution of hot hydrogen proceeds intermittently from a viscid interior, or else fresh hydrogen is added from time to time by external meteoric accessions.

The bright-line, long-period variables of Secchi's third type are connected by their spectra with the last stages of the solar type. I interpret them in this way: As condensation progresses towards its last degree, consistent with the maintenance of stellar functions, central heat becomes excessive, while it is more and more difficult for inner hot material to be transferred to the surface, because viscosity is so great as to be the precursor of final solidification. Under these circumstances, there is a recrudescence of explosive power. Central explosions, no longer of sufficient strength to disrupt the body as at the end of the Orion era, are nevertheless strong enough to break through the dense substance of the sphere, casting up above the heavy metallic vapors which rest upon the cooling photosphere, prominences of enormous size and of vivid luminosity. Chromospheric radiation begins to approach that of the photosphere in intensity. Lockyer* has rejected the supposition as to "gigantic supra photospheric atmospheres" in these stars in favor of a primitive meteor-swarm theory, but without considering the undoubted affinities with the solar type.

The formation of a vast hydrocarbon atmosphere is the most important characteristic of the last stage of stellar evolution, constituting Secchi's fourth type. The cessation of hydrogen eruptions and the spectral change to dark hydrocarbon flutings appears to be sudden, since there are no intermediates, and perhaps coincides with central solidification and absence of further central explosions.

It would be interesting to inquire how far the change of electrification from the negative hydrogen spectrum of solar and earlier stars, to the positive hydrogen spectrum in the banded variables, may have been brought about by explosions; for it is hardly possible that the enormous electric charges con-

* *The Meteoritic Hypothesis*, p. 352, *et seq.*

centrated at the center and periphery of a body of stellar dimensions should change sign without a literal turning inside out of the body. This argument assumes that there are actions going on at solar centers which generate electricity, and that the processes producing the original electrification of stars, formed out of the same ingredients in nearly identical proportion, must always give an external electric charge of the same sign. Since there are no exceptions to the order of brightness of the hydrogen lines in the same class, this argument seems warranted.

If the variability of the white stars found in clusters is an indication of youth, that of the red stars, on the contrary, must be attributed to some change connected with old age. In the younger stars there is tidal action due to close proximity of newly formed and as yet barely sundered masses. Periods of a few days, or even of a few hours, indicate a superabundant vigor.

The variability of the red stars has for its characteristic feature that the length of the period increases with the redness of the star, the progression from periods of 50 to 500 days being attended by a variation of color from orange to full red.* Like the geysers, which in youth have a frequency of a few hours, but in old age spout in a period of as many days, this change points to a waning eruptive force.

Professor Hale† finds a close similarity between the 5th and 6th divisions when limited regions in the green or the violet regions are compared. This applies both to the number and relative intensity of the lines in these parts. Other regions of the spectrum are entirely different, but here again there is a close resemblance between the spectra of stars in the 5th and 4th divisions. Hence there can be no doubt that the 5th is a transition type between the 4th and 6th divisions, and that it is a truly stellar form, and not intermediate between a meteoric swarm and a star. If bright lines reappear in the spectra of the 6th division, as indicated by Professor Hale's observations, reminding us in this respect of the earliest stars, the circumstance cannot overweigh the immense discrepancy between the energy of the violet rays in the first and the last types.

There is one other fact which, if it stood alone, I am free to admit, would shake my confidence in the position assigned to the stars of the 6th division. Mr. J. A. Parkhurst finds that stars having spectra of the 6th division congregate in and near

* Law formulated by Lockyer, "Meteoritic Hypothesis," chap. 43, from the "Catalogue of variable stars," by S. C. Chandler, *Astronomical Journal*, vol. viii, p. 81, 1888, and from Duner's "Les Étoiles à Spectres de la III. Classe," Stockholm, 1884.

† George E. Hale, *Astrophysical Journal*, vol. ix, p. 273, 1899.

the Milky Way, as do the Orion stars.* This and the bright lines in the spectrum might incline us to group the hydrocarbon stars with those in which helium plays a leading part; but we cannot thus combine stars whose surface temperatures are the highest and the lowest known. These stars are at the opposite poles of development. Can it be that the thing which has been is the thing which shall be again, that entrance and exit communicate, or that these most ancient stars are relics of an antecedent galaxy, out of whose ashes a new starry heaven has sprung?

Legitimacy of the Hypothesis of Elemental Destruction and Genesis.

If the explanation of these appearances of gigantic explosive phenomena which has been suggested, is rejected, what other can take its place? And if the hypothesis is found to afford a way out of other dilemmas which have long been recognized, does not the speculation gain a weight which deserves further trial of its efficacy to explain difficulties and to stand tests? The hypothesis of elemental dissociation, or atomic dissolution, far from being opposed by known facts, is suggested by many familiar chemical decompositions. Among the many suggestions from eminent chemists which are in the same general direction, I will only refer to those of Crookes.

Sir William Crookes has represented the recurrent properties of the series of chemical elements, indicated by Mendeleeff's periodic law, by distributing the elements along a cuspidate helix, whose widening spirals express a relation between the gravitational constants of the atomic weights, determined by the successive addition of the same quantity of electricity, conferring the property of valency and special chemical attributes, combined with some thermal property; and the idea is put forth that these relationships point to some community of origin, and to some sort of evolution of elementary properties. The series is certainly very suggestive. My conception of its meaning is that the heavier atoms are the more complex, and that their formation has required a greater expenditure of energy and a longer duration of development. Like the higher forms of life, they are the last to appear in time, and are also the rarest.

"Bodies not in harmony with the present general conditions have disappeared, or perhaps have never existed. Others—the asteroids among the elements—have come into being, and have survived, but only on a limited scale, whilst a third class are abundant because surrounding conditions have been favorable to their formation and preservation."†

* *Astrophysical Journal*, vol. viii, p. 239, 1898.

† W. Crookes, *British Association for the Advancement of Science.* Report for 1886, p. 561.

The very definition of an element is provisional and confesses "intellectual impotence." Admitting the unsatisfactory nature of the foundations of chemical knowledge, "it is important to keep before men's minds the idea of the genesis of the elements; this gives some form to our conceptions, and accustoms the mind to look for some physical production of atoms. It is still more important to keep in view the great probability that there exist in nature laboratories where atoms are formed and laboratories where atoms cease to be."*

Heat and pressure favor the dissolution of certain chemical compounds, or the transformation of complex and unstable forms into simpler ones. The common mode of preparing pure metals is by the action of heat on complex mixtures of compounds. Chloride of nitrogen breaks up into its component elements with explosive violence by simple percussion. All compounds have temperatures of dissociation, more or less high, at which they are completely resolved into their elements. If we have hitherto failed to decompose the elements, we may infer that it is because the pressures or temperatures at our command have not been great enough.

Pressure, and not heat, is to be invoked as the prime factor in atomic dissolution. The process is not reversed by any fall of temperature, and therefore is unlike the dissociation of chemical compounds by heat. The present suggestion differs from those of Hunt and Clarke, which foresaw only an extension of processes already known. Lockyer also has predicated heat as the cause of atomic dissolution, whereas in the present view it is its consequence.

An objection to the hypothesis of elemental destruction may be urged, since, while it is conceivable that the elements may be decomposed by great pressure and intense heat, there is no permanent process in nature which does not move in cycles. If atoms can be destroyed, how and where are they reproduced? Without such reproduction the resolution of the material universe into one or more forms of matter of small atomic weight would be more probable than its actual wonderful diversity and the considerable atomic weight of its leading constituents.

As to the history of material substances in their purest or atomic forms, there are only two alternatives. Either the atoms are eternal and unchangeable, in which case suns may grow cold and disintegrate, and new systems may be built of their fragments at remote intervals,† permitting a kind of

* *Loc. cit*, p. 560.

†"Two bodies, each one-half the mass of the sun, moving directly towards each other with a velocity of 476 miles per second, would by their concussion generate in a single moment 50,000,000 years' heat," says Croll in his paper on the "Probable Origin and Age of the Sun" (Quarterly Journal of Science, July, 1877), quoted in the "Autobiographical Sketch of James Croll, with Memoir of his

alternation or slow cycle; or, on the other hand, if atoms perish in stellar foci, they must be reborn in the interstellar spaces. Is there any way in which atoms can be conceived to originate in free space? I think that we begin to have a glimmering perception of such a possibility. Although it is customary to assume that the ether is completely devoid of viscosity, the relative scarcity of the fainter stars indicates that a minute fraction of the radiation which passes through the ether from myriads of stars is retained by that medium, eventually extinguishing the rays. If retained, the radiation must perform work. The only permanent change which can be effected in the ether is the imparting of that structure which constitutes matter. It becomes increasingly probable that atoms are ethereal vortices. I have only room for the most cursory treatment of the subject.

The Vortex Atom as a Possible Solution.

The vortical hypotheses of Descartes were vague and preposterous. Those of Swedenborg were more rational, but lacked mathematical refinement. His conception of a gathering of something like a hundred or a thousand cored vortices (somewhat similar to simple vortices of the type devised by Hicks) forming the universal luminiferous medium, which, flowing vortically in a circumscribed volume, produces a vortex of the second order, constituting one of the least particles of such atmospheres as surround the earths in the starry heavens,* has a remarkable analogy with Professor J. J. Thomson's discoveries, from which it follows that somewhere in the neighborhood of a thousand corpuscles are consociated in the hydrogen atom.† Helmholtz's splendid studies of aerial vortex rings,‡ and Lord Kelvin's recognition§ that similar movements in a frictionless medium, such as the luminiferous ether has been assumed to be, will give the permanence required in atoms, lent considerable stability to the doctrine of vortex-atoms; and the deeply mathematical discussion of Professor J. J. Thomson,¶

Life and Works," by J. C. Irons, London, 1896. p. 320. Herbert Spencer, in a letter to Dr. Croll (*loc. cit.*, p. 322), points out that "instead of the formation of bodies thus raised to high temperature, and continuing thereafter to radiate heat for long periods as suns, the argument is rather to the effect that the heat evolved by such collisions, taking place with the enormous velocities eventually acquired by stars gravitating into clusters and coming into collision, will have the effect of dissipating the matter they are formed of into the gaseous state and eventually into a nebulous form." Letter of 24th February, 1877.

* Emanuel Swedenborg, *Principia*, Part I, Chap. 6, Arts. 2, 20, 34, 38; Chap 7, Arts. 3, 4, 6, 7 and 20 (subsection 1).

† J. J. Thomson. "On the Masses of the Ions in Gases at Low Pressures," *Phil. Mag.* (5), vol. xlviii, p. 547, 1899.

‡ H. Helmholtz, "On Integrals of the Hydrodynamical Equations which express Vortex-motion," translated by P. G. Tait, *Phil. Mag.* (4), vol. xxxiii, p. 485, 1867. from Crelle (1858).

§ W. Thomson, "On Vortex Atoms," *Proc. R. S. Edinburgh*, vol. vi, p. 94, 1867.

¶ J. J. Thomson, "On Vortex Motion," 1882.

leading to partial explanations of the valency of the atoms, gave the hypothesis one more analogy. But the researches of Hicks,* by establishing relations between vortex motions and the thermal properties of the elements, have done more than all the others to give a stable foundation to the vortical doctrine.

Regarding the vortex-atom theory as almost certainly true, it seems to me probable that there is some connection between ethereal wave-motion and the origin of vortex-motion in the ether. If the reciprocating electro-magnetic motions of an ether-wave are not absolutely reciprocal or self-destructive, a minute fraction of the radiant energy of the stars will remain behind in the ether. We know from the atomic changes shown by the Zeeman effect,† and from the opposite absorptive effect in the magnetic field discovered by Righi,‡ that magnetism is able to produce a temporary change in atomic movement. Is it not possible that electro-magnetic waves originate the permanent vortex movements of the ether? In this case every stellar track must be strewn with atoms, and even in the most dimly lighted recesses of space matter is slowly forming.

The myriad-age-long history of an atom, if it could be traced, would be the story of the evolution of a particular form of motion through the accumulation of many vicissitudes. That in spite of the very great differences in these stories of elemental change, the elementary forms of matter are few in number, can only be accounted for by assuming that the number of possible forms of vortex-motion along these lines is limited by spatial conditions.

Newton in his "Hypothesis Touching Light and Color" suggests that "all things may be originated from ether," § but without distinguishing the substance of the ether from an attenuated form of matter.

The modern conception of the ether lends itself more readily to a theory of the ethereal origin of matter.

The different velocities with which various orders of material particles may be propelled by the electric current gives us a

* W. M. Hicks, "Researches in Vortex Motion, Part III. on Spiral or Gyrostatic Vortex Aggregates," *Proc. R. S. London*, vol. lxii, p. 332, 1898.

† See the *Astrophysical Journal*, vol. v, p. 332; vol. vi. p. 48, p. 378; vol. vii, p. 131. p. 163; vol. viii, p. 45, p. 48; vol. ix, p. 47; vol. xii, p. 120; *Phil. Mag.* (5), vol. xliv, p. 55, p. 255, p. 503; vol. xlv, p. 197. p. 325; vol. xlvii, p. 165.

‡ A. Righi, *R. Accad. Lincei*, Atti. Ser. 5, vol. vii, sem. 2, p. 41 and 338, 1898.

§ "Perhaps the whole frame of nature may be nothing but various contextures of some certain aetherial spirits or vapors, condensed as it were by precipitations. * * * Thus, perhaps, may all things be originated from æther," (Newton's Letters, etc., *Phil. Mag.* (3), vol. xxix. p. 190, 1846). He also suggests that "nature is a perpetual circulatory worker, * * * and as the earth, so perhaps may the sun imbibe this spirit copiously to conserve his shining, and keep the planets from receding further from him," and thus "that the vast ætherial spaces between us and the stars are a sufficient repository for this food of the sun and planets" (p. 192).

mode of attack which is full of promise. Still more powerful are the new magnetic methods. The difference of frequency in the Zeeman components of a Fraunhofer line is constant for all the lines of a group, even through a series of homologous elements, but differs in different groups of lines for the same element.

The problem of the composition of the elementary atom has been approached by the study of

(a) spectral series,
(b) enhanced lines,
(c) the Zeeman effect.

By these tokens we may conclude that the atoms are resolvable. It may be beyond our power to actually separate and sort the various component motions, but they may now be rationally conceived. A host of facts has been presented for mathematical analysis, and a problem has been set before us of even greater interest than that of the celestial motions, which heretofore has been the noblest of all.

Relative Abundance and Distribution of the Elements.

If the atoms are indeed in process of formation in space by absorption of radiation, there must be a general tendency to an average composition throughout space, and a corresponding general resemblance in the aggregates of matter resulting from concentration. There is, on the whole, a considerable similarity in stellar spectra. The divergences from a common type are not greater than might be anticipated from rearrangement of materials and thermal changes, occurring subsequently to the first concentration, with a small residual change which furnishes an argument in favor of the present hypothesis. Gaseous nebulæ cannot be admitted into the argument, since the relative simplicity of their spectra is due to the absence of conditions suitable for exhibiting the radiations of their more complex ingredients, and not to actual simple composition. The rapid transformation of spectra of temporary stars to the nebular type proves this.

In opposition to the idea of an average composition of matter in all parts of space must be placed the very different densities of the planets; but since they have probably been formed from our sun long after the original aggregation, and when heterogeneity had already developed in the parent mass, this fact has no bearing on the argument. We might say the same of the differences in the composition of meteorites, if we were as confident of their origin as we are of that of the planets. On the whole, the secondary origin of comets and their meteoric products seems to be indicated.

The relative abundance of the elements remains a puzzle on any hypothesis. Oxygen and silicon prevail in the outer part of the earth, hydrogen and calcium on the outside of the sun; but the earth's mean density requires that a large part of its interior shall consist of something not far from the density of iron; and the prevalence of this substance in meteorites, as well as its relative abundance in the sun, implied by the breadth and intensity of many of the iron lines in the solar spectrum, suggests that iron may turn out to be one of the most abundant elements in nature. If so, it may be something more than a coincidence that iron is a highly magnetic element, and that magnetism has given us a means of changing, if only temporarily, such a persistent elemental property as the wave-length of spectral lines.

Until someone shall suggest criteria for the stability of different possible forms of vortex-motion, I do not see how we can go farther in this direction.

Properties of the Luminiferous Ether.

I shall not enter upon questions relating to the constitution of the unmodified ether previous to the inauguration of the ethereal movement constituting atoms: whether the ether is composed of vortex-filaments giving a fibrous structure and a quasi-elasticity; whether the rectilinear motion of an atom through the ether is to be likened to the propagation of a wave in water, where the wave advances, but not the particles of the medium; or whether, like an aerial vortex-ring, the same ethereal particles continue perpetually in an individual atom; whether, indeed, the ether can be said to have "particles" in this sense; whether the intrinsic motion of the ether is circulatory, and all change in the ether is a compounding or a propagation of rotational energy; etc. But the question of the relation of the ether to gravitation is of such importance that it must be considered. In the ninth edition of the Encyclopædia Britannica, Maxwell has given a computation of the density of the ether, referred to water, getting $9{\cdot}36\times10^{-19}$. A numerical mistake is nearly balanced by the use of Pouillet's value of the solar constant. Correcting the error and substituting three small calories per minute on each normal square centimeter (0·05 radim) for the solar constant, the density of the ether comes out $9{\cdot}17\times10^{-19}$. The whole computation rests on the assumption that the amplitude of an ether-wave from the sun, near the sun's surface, is $\frac{1}{10\,\pi}$ of the average wave-length. There is not the slightest evidence that there is any such relation between ethereal amplitude and wave-length; and the array of figures has not even qualitative value, since the method involves some unsafe tacit assumptions.

If atoms are constituted by vortex-rings in the ether, and if the weight of an atom depends on the energy or complexity of this peculiar form of vortical motion, the logical conclusion is that the absence of vortex-rings in the free ether implies absence of gravitational mass, or a density of zero. Substance there must be, using the term in a general, although not in a merely metaphysical sense; but of ordinary matter as distinguished by the possession of gravitational action, ether has none, on this supposition. Energy must be defined as the modification of ethereal rotation, or the establishment of rotation at new points in the ether. When temporary vortex filaments spring up in the ether between positively and negatively electrified bodies, this gives the energy of electric attraction—an energy which depends on the number of filaments, or lines of electric force, and their distribution, being greater when the distribution becomes more strongly asymmetrical. The formation of temporary closed vortex-filaments around an electric current gives rise to magnetic attraction. The forming of more permanent vortex-rings in the ether with resulting gravitational attraction, demands an energy which is greater when the internal motion is more complex. The destruction of a vortex-ring, or its simplification, sets energy free. We may concede that there is doubtless a preservation of entropy by some sort of mechanism, and that the system is in some way reversible; but by the "system" of which I now speak, is meant a connected train of processes as wide as the physical universe; and for the working of this system, even for a single throw, an immense time is demanded. The change from the gaseous, or ultragaseous state to that of the free ether is not like that from a solid to a liquid, or the similar transformation of a liquid to a gas, requiring the latency of a certain amount of heat. Although appearing like a rarefaction, the change in question is quite different. Its ratio to the previous changes is of the $\frac{0}{0}$ form and cannot be guessed from the previous operators, but must be determined in a new way.

Most attempts to solve the problem and discover the properties of the ether, have proceeded on the assumption that the ether resembles a rarefied gas. In this way DeVolson Wood* found that its specific heat must be something like five millions of millions, that of water being unity. The computation may not be without value, although it is necessary to modify the very meaning of the word "heat," or energy of molecular motion, when treating of a substance which has no molecules, nor rectilinear motions such as the kinetic theory of gases assumes. The numerical value deduced by this computation

* *Philosophical Magazine* (5), vol. xx, p. 402, 1885.

reminds us that the ether is a very peculiar substance, and that its properties are such as would be considered unconscionably exaggerated, if stated of ordinary matter. Consequently we are not doing violence to known facts by giving extraordinary properties to ether, nor by predicting that the change from ether to matter, or the reverse, must involve the disappearance or reappearance of an enormous amount of energy. It appears, therefore, not improbable that the destruction or simplification of material atoms is capable of setting free the forces which are required for stellar disruption. If the ether has a capacity for absorbing enormous energy in becoming converted into atoms, then this energy is set free when the atoms are destroyed, and the duration of the sun is thereby prolonged.

The remaining links in the argument are surmises, or are necessary to the completion of the cycle. Their justification is the conviction that there must be a cycle of some sort; that if we find water flowing continually down hill, there must be some process by which it gets to the top again. The suggestions are made more as questions for solution than as answers. But I may be permitted to point out that the present attempt at an answer to the question: How does the sun maintain its heat, and how long may the sun endure? reconciles several dilemmas.

Solar Sustentation.

The logical necessity for some kind of cycle in the relation of the sun to surrounding space was doubtless the foundation of Siemen's attempt to devise a working theory in which the sun was regarded as a kind of ventilating fan, drawing in fuel from a universal gaseous atmosphere of elementary composition, and casting it off as burned matter to be dissociated by radiation. The hypothesis has been so completely demolished by Hirn and others that it is unnecessary to refer to it any further than to say that it is entirely inadequate, if for no other reason, because the employment of the solar rotation as a motive power must destroy the rotation, and thus the entire scheme in a comparatively short time. But the shortness of the available time of the sun's present radiant power is also a serious difficulty which must be urged against the contraction theory, because the duration of the earth, since it has been cool enough to sustain life, is necessarily shorter than that of the sun, and yet it outspans the probable term of solar existence.

Professor See* finds that the past duration of solar radiation at the present rate, for which Helmholtz obtained a value of 18,000,000 years by the contraction theory, assuming a homo-

* T. J. J. See, *Astronomische Nachrichten*, vol. cl, p. 177, 1899.

geneous sphere, must be increased in the ratio of 176,868 to 100,000, to allow for heterogeneity, according to Lane's theory of the density of the sun's interior, giving a past duration of 32,000,000 years; and as contraction to one-half the present radius, giving density=11·2 times that of water, would probably end the gaseous sun, a total duration of 36,000,000 years is inferred.

This computation, like its predecessor, rests upon Pouillet's value of the solar constant, which is too small. Lord Kelvin* had already substituted Langley's value of the solar constant, getting 12,000,000 years for the age of a homogeneous sun, or 20,000,000 years, "taking fully into account all possibilities of greater density in the sun's interior, and of greater or less activity of radiation in past ages."

Lord Kelvin's computation by Fourier's method gives about 100,000,000 years for the earth's age,† assuming a conductivity of the terrestrial substance equal to that of most surface rocks, and an initial temperature of 3870° C. If the interior of the earth is highly conductive, cooling must have proceeded to a great depth, and a longer time will have been needed to establish the present distribution of temperature near the surface.

The mean density of the earth and other facts indicate an inner core of metallic composition. Moreover, the continental relief, as compared with the depth of the oceanic basins, and the contortion of strata by lateral compression, bear witness to a contraction, which proves that cooling of the earth has proceeded to a much greater depth than would be allowable on the supposition of a conductivity equal to that of the surface rock. Hence we have an added argument for an interior conductivity approaching that of metals. A longer duration is to be preferred for this reason.

Many regions of the earth have been invaded by volcanic action in geologically recent time. This is especially the case in those disturbed districts where most of our mining operations are conducted. The rise of temperature with increasing depth is more rapid in these places than it would be normally. The more rapid the rise of temperature, the shorter is the calculated duration of cooling. The rate of subsidence of regions where sedimentary deposits accumulate, is slow enough for the subterranean isotherms to rise into the newly formed rocks, and chemical action perhaps makes them local sources of heat and volcanic action. Some of the deepest wells in rocks which have been undisturbed since Paleozoic times give gradients of temperature much lower than the average. Instead of taking

* W. Thomson, "On the Sun's Heat." Roy. Institution of Great Britain, Jan. 21, 1887; *Nature Series*, Popular Lectures and Addresses, vol i. p. 397, 1891.

† W. Thomson, *Trans. Royal Soc. Edinburgh*, vol. xxiii, p. 164, 1862.

a mean of all known observations, it seems proper to choose those which give the slowest rates of thermal increment, for these are the ones which have been least interfered with by local volcanic action, and which most nearly correspond to the deeper and more stable gradients. The substitution of these slowest rates increases the time scale.

Clarence King* has given a different method, depending on the fusion temperature of basalt as determined by Barus, and assumptions as to the average composition of the earth's outer layers, which are supposed to be basaltic. But the eruptive rocks are just those which have been, as it were, sweated out from the crust, leaving the more refractory materials behind. Grant this, and the average melting point of the residual rocks must be raised, increasing the time-estimate by this method. Taking the initial temperature of solidification as 1741° C., Clarence King finds for a thermal gradient of 1° F. in 50 feet, 20×10^6 years, and for 1° F. in 75 feet, 46×10^6 years, on the hypothesis of a solid earth. Neither estimate takes any account of the greater conductivity of the deeper layers. If this were done, it might be necessary to extend the computed durations several times.†

Finally, if the gradual modification of living forms by natural selection is a fact, the longest durations named are none too long for the numerous successive faunas and floras made known to us by paleontology.

We need an earth-duration of several hundred million years to meet the requirements of evolutionary theory and of thermotics. The sun, by its contraction, will give only 20,000,000. Hence the dilemma.

The hypothesis of the development of solar energy by atomic dissolution greatly extends the duration of the sun, in all probability doing away with this dilemma.

The companion hypothesis of an atomic genesis by luminous impulses, in addition, fulfills the philosophic necessity for a cosmic cycle which shall restore the ancient order, and answers the question: What becomes of the light from these myriads of stars?

Washington, D. C.

* This Journal (3), vol. xlv, p. 1, 1893.

† See Professor John Perry, "On the Age of the Earth," *Nature*, vol. li, p. 582, 1895.

ART. XVII. — *Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN. (With Plate VI.)

[Continued from p. 128.]

Limnocyon Marsh.

Limnocyon Marsh, this Journal, August, 1872, p. 6, Separata;
Thinocyon Marsh, this Journal, August, 1872, p. 12, Separata;
Oxyænodon Wortman, Bull. Amer. Mus. Nat. Hist., 1899, p. 145;
Telmatocyon Marsh, this Journal, May, 1899, p. 397.

A group of small or medium-sized Creodonts ranging in time from the beginning of the Bridger to the close of the Uinta epoch, and, as far as known, having the following principal characters: Dental formula I.$\frac{3}{3}$ C.$\frac{1}{1}$ Pm.$\frac{4}{4}$ M.$\frac{2}{2}$; first upper and lower premolars two-rooted (except in *Limnocyon dysodus*); last superior molar transverse and little reduced; two subequal inferior molars with internal cusps and moderate-sized basin-shaped heels; fibula articulating with calcaneum; astragalus moderately grooved; femur with small third trochanter; deltoid crest of humerus reduced; distal end of humerus broad, with prominent supinator ridge and an entepicondylar foramen; metapodials of fore feet short and phalanges elongated; carpus unknown.

The genus *Limnocyon* was described by Professor Marsh in August, 1872, from a series of superior teeth which were not in place in the maxillary. A second species was proposed in the same paper upon a specimen consisting of both mandibular rami, one of which contains the last premolar and first molar, together with all the alveoli. In the same paper Professor Marsh proposed a second genus, *Thinocyon*, upon an entire left mandibular ramus, containing a few of the teeth in good condition and the alveoli and roots of all the others. In June, 1899, I proposed the genus *Oxyænodon* upon a well-preserved half of a skull, in which both the upper and lower teeth are present. In May, 1899, Professor Marsh, upon my advice, placed *Limnocyon verus* as synonymous with *Sinopa*, and proposed for the second species *L. riparius*, the generic name *Telmatocyon*. The reason for this advice was as follows: The type of the genus consists of the dissociated upper teeth, in which the superior molars are almost, if not quite, indistinguishable, in structure at least, from those of certain species of *Sinopa*, and as the number in this latter group is three and no two-molared type was at that time known, it was quite naturally supposed that the type specimen of *L. verus* was a *Sinopa*.

The type of *L. riparius*, having but two subequal lower molars, was otherwise unknown, and was regarded as a distinct genus. The relationship with *Oxyænodon* was entirely overlooked. The unstudied part of the collection affords much additional material, and it is now quite evident that the number of superior molars in *L. verus* is two instead of three. The association of upper and lower teeth in this material renders it clear, moreover, that the type of *L. riparius* is the lower jaw of *L. verus*, and on this account I do not hesitate to unite them. I also arrange *Thinocyon* and *Oxyænodon* in this genus, but, as already remarked, it may be found, with more complete information, that they represent distinctive generic modifications.

Limnocyon verus Marsh.

Limnocyon verus Marsh, this Journal, 1872, p. 6, Separata.

Originally established upon a superior series of teeth of the right side, figure 71, with the first premolar only, in place.

71

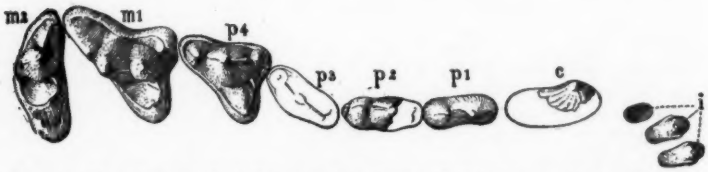


FIGURE 71.—Series of right superior teeth of *Limnocyon verus* Marsh; crown view; three halves natural size. (Type.)

The two middle incisors are present, but they do not present any characters of unusual importance; their roots are much compressed from side to side, like certain members of the Mustelidæ, and their crowns are obtusely pointed and rather narrow. The canine is represented by fragments only, but these are sufficient to indicate that it had the usual size and form of this tooth among the Carnivora; its surface is traversed by characteristic longitudinal grooves and ridges, much as in certain species of reptiles. There are apparently no traces of these grooves and ridges upon the canines of the other species of the genus (except very faint ones in *L. veloæ*), and it may be taken to be diagnostic.

The first premolar is two-rooted, with a conical, more or less recurved, principal cusp, and a rather extended heel bearing a small cusp; it is placed immediately behind the canine without the intervention of a diastema. The second premolar is only partially preserved in the type, but is present in many other specimens in the collection. The third premolar is missing in

the type, but in other specimens is similar to the first but larger. There is no internal cusp as in *Oxyæna*. The crown of the fourth is made up of the usual elements found in the typical sectorial premolar, although certain parts are little developed. There are two main external cusps, together with a small but distinct anterior basal cusp; to these is added a relatively large internal lobe, which is placed opposite or a little anterior to the large principal external cusp. The posterior external cusp is proportionally small, and the posterior

72

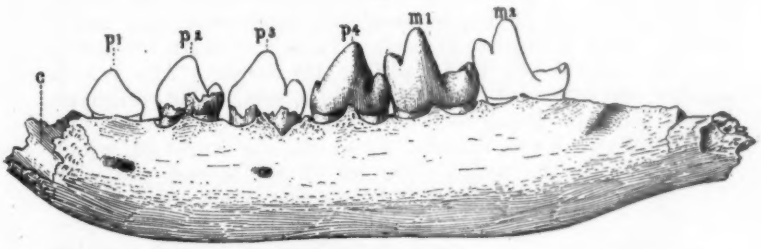


FIGURE 72.—Left mandibular ramus of *Limnocyon verus* Marsh (type of *Limnocyon riparius* Marsh); side view; three halves natural size.

border of the main cusp is little produced, so that the shear of this tooth cannot be said to be very perfectly developed. The first molar is the largest tooth of the series; its crown is composed of two principal external cusps, well separated, a strong blade-like postero-external spur, between which and the postero-external cusp is a deep vertical fissure, a basal antero-external ledge, and a large lunate internal cusp. The large postero-external spur, together with the postero-external cusp, furnish the principal shear, and constitute the chief sectorial organ of the superior series of teeth. The last molar is relatively large, three-rooted, and transverse; its crown is composed of one main external cusp, external to which, and separated by a slit-like fissure, is a sharp ridge, which has more or less of a sectorial function. The usual internal lunate cusp, together with distinct anterior and posterior intermediates, are present, but the postero-external cusp is vestigial or wanting.

73

FIGURE 73.—First molar and fourth premolar of the preceding figure; inside view; three halves natural size.

The type of *Limnocyon riparius*, figures 72, 73, which I take to be the same as *L. verus*, consists of the greater part of both mandibular rami and a portion of a first superior molar. The specimen

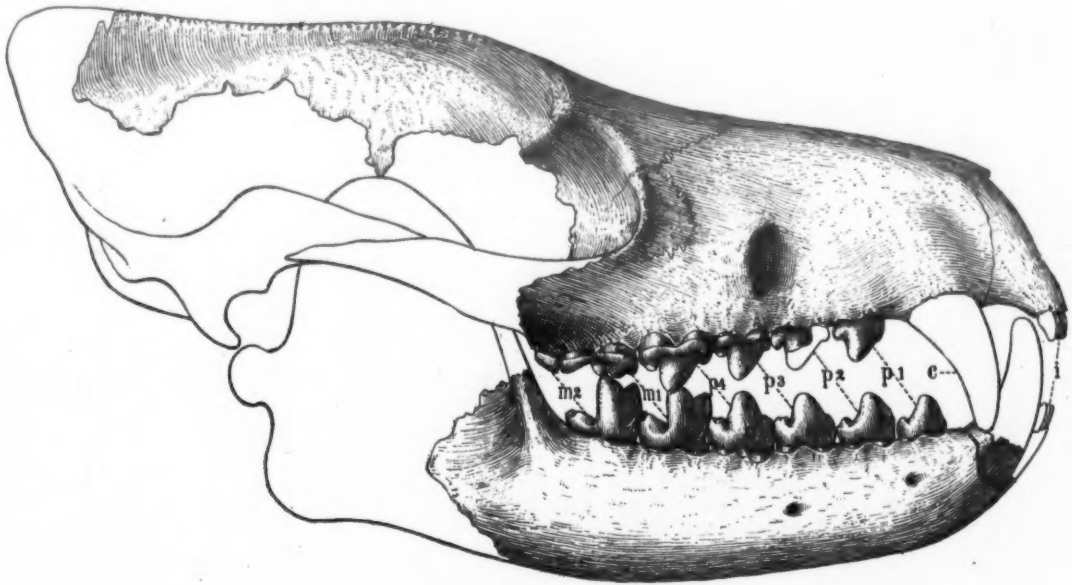
does not exhibit very clearly the number of incisors, but in others which agree with it very closely, the number is three. The first premolar is two-rooted and is placed close behind the canine, without diastema. All the other premolars are likewise implanted by two roots, and are much crowded in the jaw. The fourth has a distinct posterior, but no anterior basal cusp. The crowns of all the premolars are rather thick from side to side, and the cusps are inclined to be obtuse and rounded. The two subequal molars, of which the first is preserved in the specimen, have the following characters: A moderately elevated trigon, with a large external and smaller internal and anterior cusps; a moderately well-developed shear, and blade-like modification of the external and anterior cusps; and a medium-sized basin-shaped heel. These two teeth are nearly equal in size, the last being a little the larger. The jaw is shallow vertically and thick from side to side. The symphysis is enlarged and extends to beneath the middle of the third premolar. There are two mental foramina, the larger of which issues beneath the anterior border of the second premolar. The coronoid is rather large and the angle is not inflected.

74 75

FIGURE 74.—Astragalus and calcaneum of *Limnocyon verus* Marsh; front view; three halves natural size.

FIGURE 75.—Fibula of *Limnocyon verus* Marsh; end view; showing articular surface for calcaneum; three halves natural size.

In one specimen a considerable part of the skull, Plate VI, together with certain parts of the skeleton, are preserved, from which the following characters may be stated: The face is rather short; the orbital cavity is relatively small; there is a distinct postorbital process and a sagittal crest of moderate proportions; there is apparently no anterior glenoid process, but a distinct postglenoid foramen; the mastoid is well exposed upon the postero-lateral wall of the skull, but the position of the stylomastoid foramen cannot be ascertained; the trochlear surface of the astragalus, figure 74, is moderately grooved and there is a distinct astragalar foramen, of about the same size and position as seen in that of the otter; the fibula is little reduced and has a considerable contact with the calcaneum, figure 75, as in the otter; the calcaneum has a moderately short tuber, a broad sustentaculum, and a prominent calcaneal tubercle; there were apparently five toes in the hind foot, and the phalanges were elongated, being but little shorter than those of *Lutra*.



EXPLANATION OF PLATE VI.

Skull of *Limnocyon verus* Marsh; side view; one and one-eighth natural size.

This species is the largest one of the genus thus far known, and the remains indicate an animal slightly larger than a raccoon, which it apparently resembled in its short limbs and heavy build. In one specimen the heel of the last molar is considerably larger than that of other individuals, and is very probably indicative of another species, but until better material is brought to light it is unwise to propose another name.

The principal measurements are as follows:

Type of *Limnocyon verus:*

Length of molar and premolar series	47·5mm
Length of premolars	31·5
Length of molars	16·
Length (antero-posterior) of fourth premolar	9·2
Transverse diameter of fourth premolar (anterior border)	8·
Length of first molar (antero-posterior external)	11·5
Transverse diameter (anterior border)	9·5
Antero-posterior diameter of last molar (middle)	5·
Transverse diameter of last molar	13·

Type of *Limnocyon riparius:*

Length of molar and premolar series	46·5
Length of premolars	29·5
Length of molars	17·
Height of first molar	9·
Transverse diameter of first molar	5·
Depth of jaw at first molar	12·
Thickness of jaw at first molar	7·
Thickness of jaw at symphysis	8·

Measurements of other specimens:

Length of calcaneum	33·
Length of astragalus	21·5
Width of astragalus	16·
Length of a first phalanx of hind foot	19·
Length of a second phalanx of hind foot	12·5

The type specimen of *Limnocyon verus* was found by Mr. J. F. Quigley of the Yale party of 1871, at Grizzly Buttes, Bridger Basin, and the type specimen of *L. riparius* was found by Mr. Oscar Harger of the same party, at the same locality. Other specimens are from Henry's Fork.

Limnocyon velox Marsh.

Thinocyon velox Marsh, this Journal, August, 1872, p. 12, Separata.

The type of this species, figure 76, consists of an almost complete mandibular ramus, containing the canine and premolars more or less complete, as well as the roots of the molars and the alveoli for the incisors. The number of the latter cannot be determined with certainty. Professor Marsh stated them as two, but it is more than probable that there were three, with the middle one pushed back out of position. The canine

76

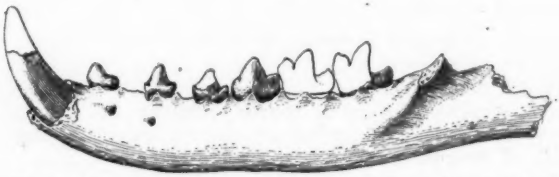


FIGURE 76.—Left mandibular ramus of *Limnocyon velox* Marsh (type of *Thinocyon velox* Marsh); side view; three halves natural size. (Type.)

is relatively large, recurved, and its surface exhibits very faint traces of the longitudinal grooving seen in *L. verus*. The first premolar is two-rooted, with an elongate heel as in this latter species. The remaining premolars resemble the corresponding teeth of *L. verus*, except that they are much smaller. The molars, of which only the heel of the last is preserved, have the same relative size and proportions as in the larger species. The jaw is unusually long and shallow, the symphysis enlarged, the inferior dental canal low in position, and the angle considerably inflected.

77

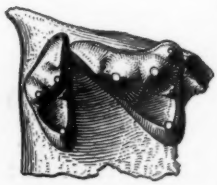


FIGURE 77. — Superior molars of *Limnocyon velox* Marsh; crown view; three times natural size.

From the numerous fragmentary specimens of this species in the collection, the following points in its structure may be stated: The last superior molar, figure 77, has two external cusps, and the antero-external basal cusp of the first upper molar is distinct and prominent; the occiput is low and broad, the sagittal crest weak, and the condyles large and divergent; there is no accessory condyloid foramen, and the stylomastoid foramen issues upon the inferior surface of the mastoid; the tympanic is not ossified into an otic bulla, and the base of the skull is broad, as in the Mustelidæ; the position of the posterior lacerated foramen is posterior and external to the periotic, as

in the Insectivora, and not postero-lateral, as in the Carnassidentia; the entocarotid enters the tympanic chamber and divides in a manner similar to that of the modern Insectivora, the main branch grooving the outer lateral aspect of the periotic, in front of, and below the *fenestra ovalis*, the other passing between the crura of the stapes and thence into the brain case; the foramen ovale is situated well within the basisphenoid and the paroccipital process projects outward and backward. There is no anterior glenoid process, but a distinct postglenoid foramen, and a deep groove in the position of the alisphenoid canal; the deltoid crest of the humerus, figure 78, is little developed, the shaft is much curved, and the distal end is broad, with an entepicondylar foramen: the ulna has a relatively short incurved olecranon, and the head of the radius is subcircular; there were five toes in the manus, the pollex, figure 79, unreduced, and the phalanges, figure 80, elongate as in *Lutra;* the femur has a strong second and a weak third trochanter; its distal end is characteristically broad, with little backward extension of the condyles, and a wide intercondylar groove; the pes is unknown.

78

FIGURE 78. — Humerus of *Limnocyon velox* Marsh; front view; two and one-fourth times natural size.

The general facies of this species is not unlike that of certain of the otters, notably *Potamotherium* of the European Lower Miocene. The likeness is seen in the low broad occiput, the weak sagittal crest, the broad base of the skull, the probable absence of the alisphenoid canal, the character of the humerus, ulna, radius, femur, and the elongated phalanges, together with probable contact between fibula and calcaneum. The character of the lower jaw and teeth, however, precludes the possibility of its being ancestral to this group. The fundamental differences are seen in the structure of the first molar, which has,

80 79

FIGURE 79.—Metacarpal of the pollex of *Limnocyon velox* Marsh; front view; three halves natural size.

FIGURE 80.—Phalanx of *Limnocyon velox* Marsh; front view; three halves natural size.

like all the Creodonts, the postero-external angle enlarged and produced into a cutting blade. It is upon this tooth that the sectorial specialization has centered, whereas in the otters it is the fourth premolar. The superficial likeness to the aquatic mustelines is very evident, however, and I do not hesitate to venture the opinion that this species was aquatic or partially so in its habits. The resemblances to the Insectivora seen in the base of the skull are very marked, and there is a possibility that the entire group may belong to this order instead of to the Creodonta.

The measurements of the species are as follows:

Type of *Limnocyon velox:*

Length of molar and premolar series	30·5^{mm}
Full length of jaw (estimated)	53·
Length of molars	11·
Depth of jaw at last molar	8·

Other specimens:

Height of occiput above base of condyles	12·
Width of condyles	15·
Width of occiput	15·5
Width of base of skull between mastoids (outside)	22·
Length of two superior molars	7·3
Width of first molar (in front)	4·8
Width of last molar	5·4
Length of humerus	40·5
Antero-posterior diameter of head of humerus	7·5
Transverse diameter of distal end of humerus	9·5
Length of olecranon of ulna	5·
Length of metapodial of pollex	7·5
Length of a first phalanx of manus	8·

The type specimen was found by Professor Marsh at Grizzly Buttes, in the Bridger Basin, and others were collected at Millersville. The horizon for the species is therefore near the base of the deposits.

Limnocyon medius, sp. nov.

Numerous remains of a species intermediate in size between *L. verus* and *L. velox* are contained in the collection, but unfortunately they are for the most part rather fragmentary. One specimen, figures 81, 82, which I select as the type, consists of the greater part of both lower laws, associated with the upper molars and a part of the premolar dentition. The principal differences, besides those of size, are seen in the superior molars. In *L. verus* and *L. velox* the two external cusps of

the first superior molar are well separated, whereas in the present species these cusps are much closer together. In *L. velox*, again, the last superior molar has two external cusps, and in *L. medius* and *L. verus* there is only one. The last two

81

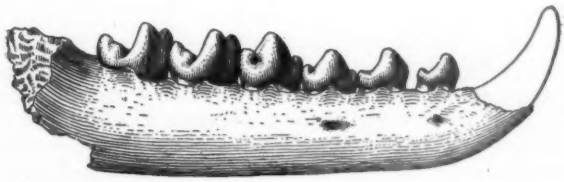


FIGURE 81.—Lower jaw of *Limnocyon medius* Wortman; side view; three halves natural size. (Type.)

species differ in the last molar, in that there is a very distinct internal cingulum in the latter, which is absent in the former.

Various parts of the skeleton are represented in the specimens, and, these apparently agree very closely with those of *L. velox*. Some parts of lumbar vertebræ are preserved in one specimen, and these show that the double tongue and groove articulations were present, as in *Patriofelis*. The deltoid crest of the humerus is reduced, the distal end is broad, and there is an entepicondylar foramen. The trochlear surface of the astragalus is little grooved, and there is a considerable contact between the fibula and calcaneum. The remains indicate an animal somewhat smaller than a Grey Fox. The measurements are as follows:

82

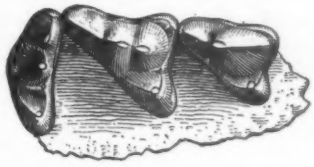


FIGURE 82.—Fourth premolar and first and second superior molars of *Limnocyon medius* Wortman; crown view; two and one-fourth times natural size. (Type.)

	mm
Length of fourth premolar and two superior molars	17·
Length of superior molars	10·
Width of first molar (in front)	6·5
Width of last molar	8·
Length of lower molar and premolar series	35·
Length of lower molars	13·
Depth of jaw at last molar	10·
Full length of jaw	80·
Length of humerus	65·
Antero-posterior diameter of head of humerus	13·5
Transverse diameter of distal end of humerus	13·5

The type specimen of this species is from near Henry's Fork, Bridger Basin, but others were found in the lower part of the deposits.

Limnocyon dysodus Wortman.

Oxyænodon dysodus Wortman, Bull. Amer. Mus. Nat. Hist., June, 1899, p. 145.

The Uinta representative of this genus, as far as known, while differing from the Bridger forms in rather strongly marked specific characters, had, nevertheless, not departed sufficiently from the general type to warrant the establishment of a separate genus for its reception. It may well be that the skeleton, when more fully known, will show characters which will necessitate its removal from *Limnocyon*, but upon present evidence, I choose to regard these characters as of no more than specific importance. That it exhibits a distinct advance in structure over the Bridger species, is shown by the fact that the first lower premolar has become single-rooted, the two external cusps of the first superior molar have been more closely approximated, and the last upper molar is considerably reduced in size. It would appear that this form is a direct descendant of *L. medius*, which is the most abundant species in the upper horizon of the Bridger, and that it was very probably also the forerunner of *Thereutherium*.

[To be continued.]

ART. XVIII.—*An Experimental Method in the Flow of Solids and its Application to the Compression of a Cube of Plastic Material;* by J. R. BENTON.

WHEN a solid body is subjected continuously to stress beyond its elastic limit, so that a flow of the material takes place, the behavior of its surface can be studied quite easily by ruling lines upon it and observing how they are deformed; from such observations it has been possible to draw some conclusions about the flow in particular cases. The interior of the body is much less accessible to experiment. Some information about the flow in the interior of metals has been obtained by comparing the "grain" of specimens which have been strained beyond the elastic limit with that of similar specimens which have not received such treatment;* but it is not possible to observe the grain in the interior of the same specimen both before and after flow, nor could this method be applied to metals which do not show grain. Again, much information has been obtained by building up bodies out of plates of the substance to be investigated; after the flow of such a composite body, sections can be made through the plates, and their form observed. This method can be used in many particular cases;† in many other cases (for example, in studying the flow during flexure beyond the elastic limit) its application would involve great practical difficulties. Besides this there is a serious objection to it on theoretical grounds, on account of the interruption of continuity of the body. And although the method enables us to study the deformation of surfaces in the body, it does not so readily furnish complete information about the motion of individual points in those surfaces.

If instead of filling the body with a system of surfaces of discontinuity, we fill it with a system of intersecting lines, these objections can be overcome. Suppose that instead of each surface of discontinuity, we introduce a framework consisting of two sets of uniformly spaced parallel straight wires at right angles to each other, all the points of intersection of the wires being melted together. Such a framework, it is true, would interfere with the continuity of the body to a slight extent; but much less so than if the body were built up out of separate plates. Furthermore, it would give the means of studying the motion of the individual points in the interior,

* H. Tresca, Proc. Inst. of Mechanical Engineers, 1867, pp. 114-143; 1878, pp. 301-345.

† Loc. cit.

since certain points on each wire can always be recognized by the intersections with other wires.

I have made an attempt to apply this method to a study of the flow in the interior of a cube compressed between two parallel plates, the faces of the cube not in contact with the plates being free.

The frames were made of fuse-wire, which was melted together at the joints. The material of the cubes experimented on was Wood's fusible alloy, it being chosen simply on account of the greater convenience of working with a substance of low melting point. Fuse-wire was used in preference to other wire because it is soft enough to follow the flow, and not cut through the Wood's metal, as harder wire might do. Only one frame was inserted in each cube; the frame was clamped in the desired position inside a cubical mould, and molten Wood's metal was poured in. After the metal had solidified, the cube was compressed gradually between the plates of a testing machine, the pressure being kept about 3000 lbs. per sq. in. Then the metal was raised to a temperature sufficient to melt it without melting the fuse-wire, and the frame was taken out. Before melting the Wood's metal after the flow, plaster of Paris was cast around it, which on hardening formed a vessel containing the metal, and prevented it from flowing away as it melted. Without this precaution there would have been the danger that the metal might have melted irregularly, and left solid masses sticking to the wire frame, which would have deformed it by their weight.

A slight difficulty occurred in the tendency of the molten metal to adhere to the fuse-wire. Coating the wires with wax did not obviate this; but the Wood's metal could be dissolved off in hot concentrated H_2SO_4.

The edge of the cube was $1\frac{3}{4}$ in. $= 4{\cdot}44^{cm}$ in every case. The friction between the plates of the testing machine and the faces of the cube in contact with them was not sufficient to prevent some flow along the plates.

The framework of wire was always placed in a plane perpendicular to the plates of the testing machine, and midway between and parallel to two faces of the cube. The original intention was to construct frameworks consisting each of two sets of parallel wires at right angles to each other. Preliminary experiments showed that the wires parallel to the plates of the testing machine remained nearly uniformly spaced and deviated but slightly from straight lines. They were accordingly dispensed with, and the frameworks used consisted each of a single set of wires, perpendicular to the plates of the machine.

Blue-prints of the frameworks were taken before and after flow, by pinning them on pieces of sensitive paper and expos-

ing to sunlight. The results obtained in this way are given in figs. 1–7.

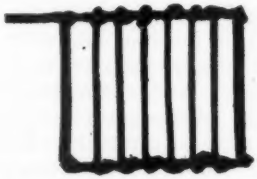


FIG. 1. Framework before flow.

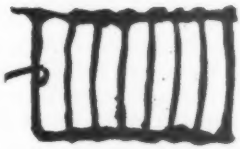


FIG. 2. Same framework after flow.

FIGS. 1, 2. The cube was compressed through a distance of $\frac{5}{16}$ in. = 0·79 cm. The faces in contact with the plates extended so as to become squares $1\frac{5}{16}$ in. = 4·92 cm on a side.

FIG. 3. Framework after flow.

FIG. 3. The cube was compressed through $\frac{5}{8}$ in. = 1·59cm. The faces in contact with the plates extended to $2\frac{1}{16}$ in. = 5·24cm on a side.

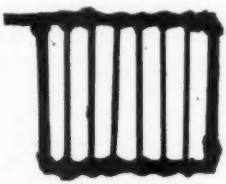


FIG. 4. Framework before flow.

FIG. 5. Same framework after flow.

FIGS. 4, 5. The cube was compressed through $1\frac{5}{8}$ in. = 2·38cm. The faces next to the plates extended to $2\frac{3}{8}$ in. = 6·03cm on a side. In Fig. 5, one cross-wire is missing next to the right hand end.

FIG. 6. Framework before flow.

FIG. 7. Same framework after flow.

FIGS. 6, 7. The cube was compressed through $1\frac{3}{16}$ in. = 3·26cm. The faces next to the plates extended to $2\frac{9}{16}$ in. = 6·51cm on a side. In Fig. 7, the cross-wire at the extreme right hand end became detached during the treatment with H_2SO_4, and is missing.

It will be observed that the wires became considerably flattened in the last stages of the flow, and that slight wavy irregularities in their form appeared, probably on account of imperfect homogeneity of the material. It is possible, however, to follow in the figures the general character of the motion, from the first stages of the flow to the last. At first the flow does not differ in any essential respect from what might be expected in view of the shape taken by the surface of the cube. But as the flow proceeds, the wires near the middle of the cube take the form of curves with two points of inflection, as shown in fig. 5, and less distinctly in fig. 7. In figs. 7, 5, and 3, a shearing of the cube parallel to the plates of the testing machine is apparent; the upper part has moved to one side, and the lower part to the other. These results are not surprising, because compression without such shearing would represent an unstable state of motion; if any cause should slightly displace the lower part of the cube with respect to the upper part, perpendicularly to the direction of the compression, then further compression would tend to increase such a displacement.

In view of this complication, it does not seem worth while to attempt to apply to the compression of a cube the mathematical theory of the flow of solids, as developed by Tresca and Saint Venant.*

University of Chicago,
September, 1901.

* Comptes rendus, lxvi, pp. 1027-1032, 1244-1246, 1305-1324; lxviii, pp. 221-237, 290-301; lxx, pp. 309-311, 473-480; etc.

Art. XIX. — *On the Occurrence of Monazite in Iron Ore and in Graphite;* by Orville A. Derby.

A small specimen of magnetic iron ore presented by Mr. John Gordon of Rio de Janeiro, from the fazenda Catita, on the lower Rio Doce in the state of Espirito Santo, presents a number of interesting features, among which is the occurrence of numerous and comparatively large grains of monazite in the mass of the ore. The ore fragment consists of a coarsely crystalline mixture of magnetite and ilmenite with adherent remnants of kaolinized feldspar and biotite, which show it to have been a segregated mass of oxides in the midst of a coarsely granular rock, probably a mica-syenite. The powdered ore, freed from the iron oxides by the horseshoe and electro-magnet, gives an extremely abundant residue of rather coarse fragments and well crystallized grains of corundum, monazite and zircon, and in microscopic slides these grains are found to the number of a dozen or more in the area of an ordinary preparation. They occur isolated in the mass of the oxides, but are more abundant in and about flakes of biotite when these are present. Of the three minerals, monazite is the most abundant and the most generally distributed, appearing in both the magnetite and ilmenite. Other interesting accessories that are confined to the magnetite, where they appear as delicate net-like partings in the twinning planes (something like the plates of tænite in meteoric irons), are a green spinel and a translucent brown titanium mineral. The ilmenite also gives on etching irregular bands showing it to be composed of a mixture of two substances of different color, and degree of solubility in hydrochloric acid. This and other interesting features of titaniferous iron ores from this and other localities will be more fully discussed by Dr. Hussak.

A specimen of graphite has recently come to hand from the region of the river Jequitinhonha in the state of Minas Geraes, which gives on washing a very abundant residue of heavy yellowish fragments, rarely crystals of recognizable form, that on microscopic and chemical examination prove to be monazite and zircon, the former greatly predominating. The only other recognizable element of the residue is a dirty white opaque titanium mineral that seems to be a pseudomorph after mica. The compact graphite is transversed by thin stringers of a decomposed micaceous mineral which also occurs in small isolated rounded patches, but these afford no more, if as much, monazite as the purer portions of the specimen. Several isolated flakes of graphite with an included grain of monazite were obtained. From the rarity of perfectly formed crystals

or of the rounded grains in which the mineral usually appears, the monazite seems to be in a state of strain in virtue of which it goes to pieces in the process of crushing and washing. On testing in a borax bead the oxalates precipitated from a solution of the residue, Dr. Florence obtained beautiful crystallizations of both cerium and lanthanum, the latter appearing much more abundantly and readily than in the many other samples of monazite that he has examined in this way. From this circumstance it may be concluded that the mineral presents some peculiarities of composition, but material is not at hand for a verification of this point.

The locality from which the specimen comes was visited in 1880 by Dr. Costa Sena, the present director of the School of Mines of Ouro Preto, who reports the occurrence of loose masses up to 100 kilograms in weight and of a vein from half a meter to a meter in width in decomposed granitoid gneiss in the bed of the Corrego do Emparedado, affluent of the small river São Pedro, which enters the Jequitinhonha from the left some 60 to 70 miles below the town of Calhau (Arassuahy). An analysis made at that time gave 85% of carbon, 4·7% of volatile matter and 7·2% of ash. Judging from the present specimen, which probably was about the same composition, the ash is composed for the most part of phosphates of the cerium group in the form of monazite.

Another specimen of graphite of similar appearance and mode of occurrence, from near São Fidelis in the state of Rio de Janeiro, presents the same phenomenon of an abundance of monazite as the almost exclusive non-carbonaceous accessory. On the other hand, several specimens of graphitic schist that have been examined give an abundant residue of titanium minerals (rutile in some cases, ilmenite in others), but no minerals of the rarer elements. This circumstance and the occurrence in the schistose types of graphite of a great amount of sericitic mica indicates a difference in the mode of origin of the two types of graphitic rock corresponding to the differences in their mode of geological occurrence. Unfortunately no specimens are at hand for verifying to what extent monazite is a characteristic accessory of the graphite occurring in gneiss and granite. As the two specimens examined, taken by chance, have shown it in relative abundance, it may be suspected that it will be found to be rather generally distributed. If so, its significance from a genetic point of view hardly needs to be mentioned.

São Paulo, Brazil, December 24, 1901.

ART. XX.—*The Molecular Weights of some Carbon Compounds in Concentrated Solutions with Carbon Compounds as Solvents;* by CLARENCE L. SPEYERS.

IN some preceding papers,* it has been shown that the equation

$$\frac{n}{N+n}=\frac{p-p'}{p} \text{ or } \frac{n}{N}=\frac{p-p'}{p'} \qquad (1)$$

expresses the vapor pressures of mixtures of liquids miscible in all proportions better than does the equation

$$\frac{n}{N}=l\frac{p}{p'} \qquad (2)$$

The latter gives absurd values towards the limits of concentration: the former gives reasonable values throughout the range of experiment. The failure of (2) is hardly to be attributed to experimental error,† because in that case the molecular weights should show far more irregularity than they do.

Moreover with such simple assumptions regarding molecular weights as are continually being made for non-volatile solutes, it was possible to plot boiling point curves for mixtures of two liquids soluble in each other in all proportions and to state in a general way when a mixture might have a maximum boiling point.‡

Last year, J. von Zawidski§ applied Margule's equation

$$\frac{dlp}{dlx}=\frac{dlp'}{dl(1-x)},$$

where x denotes the fraction of a gram-molecule of one liquid and $1-x$ denotes the fraction of a gram-molecule of the other liquid, to a mixture of two liquids miscible in all proportions. In this differential form, the equation seemed to be unsatisfactory, and to integrate it constants of uncertain value are introduced complicating the theoretical investigation. Moreover, the equation will not agree with experiment unless molecular association is granted. Taken altogether, Margule's equation is more complicated than equation 1, far more so, and in no case does it give results more concordant with fact than equation (1) does. For one mixture, that of acetone and chloroform, equation 1 fails. But so also does Margule's equa-

* Journ. Phys. Chem., ii, 347, 362, 1898; Journ. Am. Chem. Soc., xxi, 282, 1899.

† Bancroft, Journ. Phys. Chem., iv, 224, 1900.

‡ This Journal, ix, 341, 1900.

§ Zeitsch. Phys. Chem., xxxv, 129, 1900.

tion. The only explanation I can suggest, and one which Zawidski also suggests, is that the two components react chemically.

On reviewing the deduction of van't Hoff's law, it seemed that neither the compression of the solution nor the heat of solution of the solute had to be considered. Both of these quantities seemed to cancel out.* It is to be understood of course that Q belongs to a reversible change. It has nothing to do with the heat of a chemical change such as the chemical reaction of a solute with solvent. For example: If Q refers to a heat of dilution, then when we remove or add solvent, which by the nature of the cycle we can do at will, then Q is either absorbed or rejected according to the nature of the solvent and solute, and when we reverse the operation, the sign of Q is reversed. But if Q refers to a heat of chemical combination, then the addition of solvent in the cycle to the solution will produce an evolution of heat and this evolution cannot be compensated in some other operation because of the nature of the cycle. See resorcinol and ethyl alcohol. With this understanding, the application of equation (2) to concentrated solution seems to be allowed by theory.

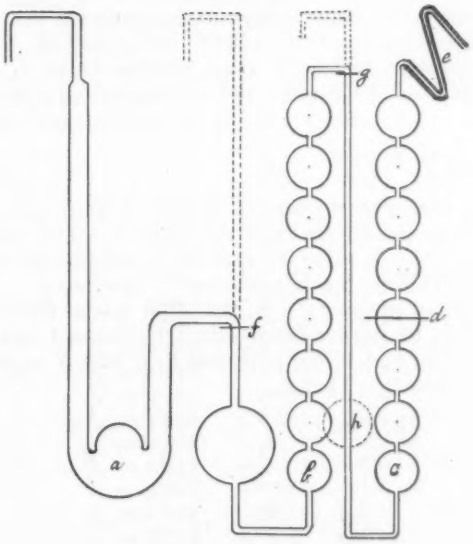
All the systems considered in the preceding papers were composed of liquids, and as there might be some disturbing action overlooked in the van't Hoff development when the solute was a volatile liquid, it seemed quite desirable to measure the relative depression of the vapor pressure for concentrated solutions of non-volatile solutes.

A few preliminary trials showed that the boiling point method was unsatisfactory, even under reduced pressure,† with such concentrated solutions. The change in temperature was too great. Moreover, theory asserts very positively that the formula for calculating the molecular weight from the change in boiling point is only valid when the heat of vaporization Q does not vary between the two boiling points. Unless these lie close together, or unless the variation of Q is taken into account, the values for the molecular weights so obtained are more or less wrong. Similarly for cryoscopic measurements.

The requirements were best met by the method of Walker‡ changing the arrangement a little, for in its original form satisfactory results could not be obtained.§ The solution was contained in a bulb tube shown by the full lines in the diagram. The solution filled the tubes to about *d*, about 40^{cc} of solution. The larger part of the solvent was evaporated in

* Journ. Am. Chem. Soc., xxi, 725, 1899.
† Journ. Phys. Chem., i, 766, 1897.
‡ Zeitsch. phys. Chem., ii, 602, 1888.
§ Journ. Phys. Chem., i, 766, 1897.

bulb *a* and this was so large that the deposited solute did not stop it up; a small part was evaporated in bulbs *b*, and the slight balance, if any, in bulbs *c*. Consequently the air passed through a liquid of almost if not quite constant concentration before it got away. The tubes connecting the sets of bulbs *b* and *c* had a bore of about 1·8^{mm}, so that the bubbles of air passing through were quite small. The tube *e* had a bore of about 0·4^{mm} and being bent as it was none of the liquid which condensed in that part of *e* which projected above the water bath could get back into *c* but was drawn out by the current of air.



In this way traps with troublesome rubber or ground glass connections were avoided. The rest of the tubing had a bore varying between 1^{cm} and 3^{cm}. This is tube 1.

The solvent was contained in a tube like 1, but the part to the left of *f* was omitted, a tube running straight up and bent over instead, as shown by the dotted lines commencing at *f*. No other variation from 1. It held about 30^{cc}. This is tube 2.

Two other tubes, just alike, consisted of a single column of bulbs each, everything to the left of *g* being cut away, a tube run straight up and bent over, and another bulb put in, *h*, as shown by the dotted lines. Each tube held about 25^{cc}. These are alcohol tubes 1 and 2.

The four were placed in a water bath whose temperature was regulated to 0·4°.

A current of air direct from the laboratory passed through alcohol tube 1, from which it took up alcohol to saturation; then, to remove all the alcohol, through three spiral tubes containing about 90^{cm} of sulphuric acid in all. The dried air then passed through the solution in tube 1 and from that into the suction apparatus.

A second independent current of air, also direct from the laboratory, passed through alcohol tube 2, then through another set of sulphuric acid tubes just like the first set, then through the pure solvent in tube 2 and on into the suction apparatus.

The loss of the alcohol tubes is proportional to the volume of air drawn through them. Let l' be the loss of one alcohol tube, let l'' be that of the other alcohol tube, L′ the corresponding loss of tube 1, L″ the corresponding loss of tube 2. Then

$$\frac{l''}{l'}\,\mathrm{L}'$$

gives what would be the loss of tube 1 if as much air passed through it as passed through the tube 2. The loss for that tube whose alcohol tube showed the smallest loss was always corrected. That is, the smallest loss of alcohol was put as the denominator in the correction, the other loss as the numerator, Let L_1 and L_2 be the corrected values for tubes 1 and 2. Then we may put L_1 and L_2 proportional to p' and p respectively in equations 1 and 2. That is,

$$\frac{a\mathrm{L}_2 - a\mathrm{L}_1}{a\mathrm{L}_1} = \frac{\mathrm{L}_2 - \mathrm{L}_1}{\mathrm{L}_1} = \frac{n}{\mathrm{N}} = \frac{p-p'}{p'}$$

and

$$l\frac{a\mathrm{L}_2}{a\mathrm{L}_1} = l\frac{\mathrm{L}_2}{\mathrm{L}_1} = l\frac{p}{p'} = \frac{n}{\mathrm{N}}.$$

Since $n = w/m$ and $\mathrm{N} = \mathrm{W}/\mathrm{M}$ we have

$$m = \frac{w\mathrm{M}\mathrm{L}_1}{\mathrm{W}(\mathrm{L}_2 - \mathrm{L}_1)} \qquad (3)$$

and

$$m = \frac{w\mathrm{M}\ 0{\cdot}4343}{\mathrm{W}(l\mathrm{L}_2 - l\mathrm{L}_1)} \qquad (4)$$

The error of the method could be partly determined by using pure solvent in tubes 1 and 2, correcting the smaller loss as given by the alcohol tubes, and comparing with the observed loss of the other tube. For instance, when pure water was used in both tubes 1 and 2:

Loss of alcohol tube 2 = 4·988 grms.; loss of tube 2 corresponding to $p = 0·960$ grm.
" " " 1 = 4·700 " " " 1 = 0·915 grm.
" tube 1 corrected = (4·988/4·700) 0·915 corresponding to $p' = 0·971$ "

$p - p' =$ 0·011

Error $= \frac{11}{971} 100 = 1·1$ per cent.

A second experiment gave an error of 1 per cent, so that the mean error would be 1·05 per cent of the quantity measured. The temperature in this case was 41·3°. In this way, the errors given in the following table were determined. The first column gives the solvent, the second column gives the corrected value of either L_1 or L_2 as the case may be, the third column gives the difference between the observed maximum L and the corrected L. When —, the corrected value is greater than the observed value. The fourth column gives the percentage error and the fifth column the mean percentage error. The sixth column gives the temperature.

Substance.	L	ΔL	Per cent error.	Mean per cent error.	$t°$
Water	$L_1 = 1·022$	−0·010	1·0		41·2
"	$L_1 = 0·971$	−0·011	1·1	1·0	41·3
"	$L_2 = 0·597$	+0·002	0·3		32·3
"	$L_2 = 0·591$	+0·004	0·7	0·5	32·3
Methyl alcohol	$L_1 = 4·044$	+0·068	1·7		44·0
" "	$L_2 = 5·220$	+0·038	0·7		44·0
" "	$L_1 = 6·266$	+0·039	0·6		44·0
" "	$L_2 = 5·146$	+0·048	0·9	1·0	43·8
" "	$L_1 = 3·159$	−0·013	0·4		31·4
" "	$L_2 = 3·360$	+0·019	0·6	0·5	32·2
Ethyl "	$L_2 = 6·814$	−0·112	1·6		44·8
" "	$L_1 = 5·441$	−0·033	0·6	1·1	44·8
" "	$L_2 = 2·880$	−0·056	1·3		26·9
" "	$L_1 = 2·022$	−0·005	0·2	0·75	26·9
Propyl "	$L_1 = 1·134$	+0·012	1·1	1·1	31·3
" "	$L_1 = 2·663$	−0·015	0·6		45·2
" "	$L_1 = 2·254$	−0·023	1·0	0·8	45·2
Toluene	$L_1 = 1·356$	+0·003	0·2		27·5
"	$L_1 = 1·384$	−0·005	0·4	0·3	27·5
"	$L_1 = 4·700$	+0·051	1·1		45·1
"	$L_1 = 4·669$	+0·028	0·6	0·8	45·2

These errors do not represent the total errors of the apparatus because in their determinations, so far as conditions will permit, the air is completely saturated with solvent vapor. But in measurements of the relative depression of the vapor pressure tube 1 contains more or less concentrated solutions and therefore one current is not at maximum saturation and the conditions are not the same as they were when the above

table was made. However no other way was found of getting at the true error.

This method of getting the molecular weights of solutes is only useful for solutions which do not change chemically when a current of air is passed through them for twenty-four hours. Moreover, the solutions must be concentrated, because all the errors are piled up on the molecular weight to an extravagant degree when the solutions are dilute, that is, when $p-p'$ is small. The weights of w, W, and M are to be considered correct as given; then the effect of an error of one unit in the determination of p and of p' gives an error in the determination of m proportional to

$$d\frac{p'}{p-p'} + d\frac{p'}{p-p'} = \frac{1}{p-p'}\,dp$$

from equation (3), and

$$dl\frac{p}{p'} + dl\frac{p}{p'} = \frac{p-p'}{pp'(lp-lp')^2}\,dp$$

from equation (4), which when $p-p'$ is small, becomes

$$\frac{p'}{p(p-p')}\,dp = \frac{1}{(p-p')}\,dp \text{ approximately.}$$

A few measurements with dilute solutions are given but they are not to be depended upon, although the results seem good in some cases. For such solutions, the boiling point method is by far preferable.

The observations and molecular weights are given in the following tables. In the first column is the solute, its ordinary molecular weight, its origin and purity; in the second, the quantity of solvent in grams; in the third, the quantity of solute; in the fourth, the corrected losses of tube $1 = p'$; in the fifth, the corrected losses of tube $2 = p$; in the sixth, the differences $= p-p'$; in the seventh, the molecular weight according to equation (3); in the eighth, the molecular weight according to equation (4); in the ninth, the temperature.

Let us consider each solution separately.

Urea in water. 50 per cent to 60 per cent urea referred, as always, to 100 parts of solution. The mean molecular weight of urea according to formula (1) is $60{\cdot}6 \pm 1{\cdot}6$; according to formula (2) it is considerably greater, $72{\cdot}6 \pm 1{\cdot}8$. This assumes that we accept the modified van't Hoff theory. If we deny the validity of the modification, then formula (2) cannot be used at all, for the necessary data as to compressibility and heat of dilution are not known. Formula (1) much to be preferred.

WATER, ordinary distilled.

Urea 60.	Solvent.	Solute.	p	p'	$p-p'$	m_3	m_4	$t°$
From Kahlbaum. Recrystallized from C_2H_5OH. Dried on steam radiator to avoid decomposition.	17·08	22·59	0·742	0·537	0·205	62·3±1·2	73·7±1·2	32·3°
	16·40*	22·48	0·377	0·267	0·110	59·7±1·6	71·2±2·2	41·3
	15·59*	23·12	0·549	0·381	0·168	60·6±1·8	73·0±1·9	"
Resorcinol 110.								
From Kahlbaum. 4·40 grams lost 0·0005 gram in partial vacuum over H_2SO_4. No further purification.	13·69	21·24	0·668	0·566	0·102	155 ±3	168 ±6	32·3°
	13·52	27·66	0·480	0·393	0·087	166 ±4	184 ±4	"
	13·73*	25·87	0·492	0·412	0·080	175 ±9	191 ±9	41·3
	14·70*	27·65	0·651	0·540	0·111	165 ±9	182 ±9	"

METHYL ALCOHOL.

From Kahlbaum. Treated with CaO for 24 hrs. Distilled off. Boiling point = 65·0°. Bar. = 762.

Urea 60.								
	26·26	6·34	3·933	3·506	0·427	63·1±2·4	66·9±3·0	28·0°
	26·78	6·99	3·455	3·035	0·418	60·6±2·3	64·7+2·4	"
	26·10	10·32	8·435	6·633	1·802	46·6±2·2	52·6±2·3	44·2
Acetanilid 135.								
From Kahlbaum and from Eimer and Amend. In partial vacuum over H_2SO_4, 3·81 grams lost less than 0·001 gram in 24 hours. Dried in air bath at 100°.	22·81	11·73	4·243	3·710	0·533	117 ±3	123 ±4	31·2°
	23·47	11·72	3·988	3·508	0·480	117 ±5	125 ±4	32·0
	20·47*	18·06	3·642	2·809	0·833	95 ±7	109 ±7	42·3
	19·30*	19·67	5·878	4·336	1·542	92 ±6	107 ±6	43·7
	19·21	19·77	14·08	10·58	3·50	100 ±4	118 ±4	44·2
Naphthalene 128.								
From Merck, marked highest purity, medicinal. Not further purified. In partial vacuum, 4·79 grams lost 0·05 gram in 24 hours.	42·34	3·067	3·073	2·992	0·081	85 ±17	87 ±17	28·5°
	28·84	5·71	8·304	7·718	0·586	83 ±12	86 ±12	44·8
	28·16	5·44	7·894	7·307	0·587	77 ±10	80 ±10	"

ETHYL ALCOHOL.

From Kahlbaum or Merck. Marked absolute. Not further purified.

Acetanilid 135.								
	27·15*	7·05	1·420	1·315	0·105	150 ±4	166 ±5	21·5°
	23·53	9·732	2·193	1·932	0·261	141 ±9	150 ±9	31·5
	27·73*	10·95	2·606	2·280	0·326	127 ±4	136 ±7	32·5
	27·51*	14·83	5·119	4·350	0·769	140 ±2	152 ±6	42·5
Acenaphthene 154.								
From Kahlbaum. White crystals. Powdered and dried on steam radiator. Turned yellow on exposure to light.	29·44	1·082	3·301	3·229	0·072	76 ±30	76 ±30	27·6°
	29·10	2·069	3·856	3·749	0·107	115 ±53	115 ±47	44·0
Naphthalene 128.	29·31	2·425	2·128	2·065	0·063	125 ±34	128 ±34	27·7°
	27·55	6·350	7·892	7·428	0·464	170 ±38	176 ±33	44·8
	25·94	6·107	6·055	5·580	0·475	127 ±18	132 ±18	45·5
Urea 60.	29·84	1·659	1·509	1·442	0·067	55 ±9	57 ±10	27·0°
	29·88	2·418	3·682	3·410	0·272	47 ±7	49 ±7	43·7

* With a somewhat different apparatus.

	Solvent.	Solute.	p	p'	$p-p'$	m_3	m_4	$t°$
Benzamid 121.	29·65	5·520	2·809	2·645	0·164	138 ±18	142 ±22	27·0°
From Kahlbaum	27·15*	8·353	4·988	4·373	0·615	101 ±4	108 ±6	42·2
	27·54*	8·119	5·049	4·442	0·607	99 ±4	107 ±7	42·2
	25·57	7·805	3·922	3·457	0·465	104 ±10	111 ±10	43·7
Resorcinol 110.	20·40	20·30	2·511	1·151	1·360	38·8±0·5	58·7±0·5	30·0°
	16·28	20·74	2·448	0·936	1·512	36·3±0·1	61·0±0·1	30·0°

PROPYL ALCOHOL.

From Kahlbaum. Treated with CaO for 24 hours. Distilled off. Boiling point 96·6°–96·9°. uncor. Bar. 766–762.

Acenaphthene 154.	27·36	2·167	3·642	3·541	0·101	167 ±52	169 ±56	45·2°
	27·08	2·176	1·756	1·716	0·040	207 ±84	209 ±84	45·3
Naphthalene 128.	28·70	3·035	0·957	0·898	0·059	97 ±17	100 ±19	29·8°
	26·52	6·970	2·124	1·998	0·126	250 ±34	259 ±35	45·5
	25·58	6·848	3·150	2·853	0·297	154 ±9	162 ±13	45·6
	23·88	6·943	2·413	2·200	0·213	180 ±16	189 ±16	"

TOLUENE.

From Kahlbaum. Treated with Na for 15 hours and distilled. Boiling point 110·3°. uncor. Bar. 770.

Naphthalene 128.	30·58	16·47	2·225	1·595	0·630	126 ±1	149 ±2	29·5°
	21·38	21·51	4·105	2·358	1·747	125 ±2	167 ±2	41·1
	19·08	22·34	4·200	2·260	1·940	125 ±3	174 ±2	45·1
Acenaphthene 154.	31·27*	6·60	1·078	0·951	0·127	145 ±5	155 ±11	20·8°
	25·44	9·093	1·833	1·495	0·338	145 ±3	161 ±3	27·5
	25·45	9·148	2·888	2·388	0·500	158 ±3	174 ±3	28·4
	25·91*	9·293	1·631	1·970	0·339	159 ±3	175 ±3	28·5°
	23·42*	10·27	2·138	1·720	0·418	166 ±4	185 +6	31·3
	20·98*	14·36	2·069	1·428	0·641	140 ±2	170 ±4	42·5
	22·94	14·60	6·237	4·452	1·785	146 ±4	174 ±4	45·1
	21·01	16·93	5·519	5·672	1·847	147 ±4	182 ±4	51·4

Resorcinol in water 61 per cent to 67 per cent resorcinol. Resorcinol is associated according to each formula and neither one is to be preferred.

Urea in methyl alcohol. 19 per cent to 28 per cent urea. At 28°, the molecular weight of urea is 61·8±2·3 by formula (1) and 65·8±2·7 by formula (2). At 44°, the molecular weight drops very much, but a solution of urea in methyl alcohol cannot be evaporated at 44° without decomposition. Moreover, after standing 24 hours another solution of the same strength and kept at 44° had altered in density and smelled of ammonia showing decomposition at that temperature. Formula (1) to be preferred.

Acetanilid in methyl alcohol. 33 per cent to 51 per cent acetanilid. In all cases, the molecular weight is below the normal. But acetanilid decomposes in solution into anilin and

* With a somewhat different apparatus.

acetic acid* and this would account for the low molecular weight. This decomposition takes place the more rapidly the higher the temperature, and we find a considerably lower molecular weight at 44° than at 31°. Neither formula can be preferred.

Naphthalene in methyl alcohol. 7 per cent to 16 per cent naphthalene. These low molecular weights are probably due to some unknown source of error, perhaps to the volatility of naphthalene in methyl alcohol vapor.† It should be noticed that the corrections are very large, emphasizing the statement that this method is only good for high molecular concentrations. Boiling point determinations show normal molecular weights for naphthalene in methyl alcohol‡ at 43·5°. Neither formula can be preferred.

Acetanilid in ethyl alcohol. 21 per cent to 31 per cent acetanilid. The molecular weights seem to be normal; no sign of decomposition. Neither formula can be preferred.

Acenaphthene in ethyl alcohol. 3·5 per cent to 7 per cent acenaphthene. The solutions are too dilute. Corrections are too large. Neither formula can be preferred.

Naphthalene in ethyl alcohol. 8 per cent to 19 per cent naphthalene. The molecular weights indicate a normal value but the corrections are too large for a satisfactory conclusion to be drawn. Naphthalene is not so volatile with ethyl alcohol vapor as it is with methyl alcohol vapor.§ Neither formula can be preferred.

Urea in ethyl alcohol. 5 per cent to 7 per cent urea. The solutions are too dilute. Indications are normal molecular weights at 27·0° and decomposition at 43·7°. Neither formula can be preferred.

Benzamid in ethyl alcohol. 16 per cent to 23 per cent benzamid. The molecular weight is probably normal at 27°. Decomposition is indicated at 42°. Neither formula is to be preferred.

Resorcinol in ethyl alcohol. 50 per cent to 56 per cent resorcinol. The corrections here are very small and yet the molecular weight is about one-third the normal. This would indicate a chemical combination of resorcinol and ethyl alcohol, in agreement with what was noticed when resorcinol was dissolved in an excess of ethyl alcohol.‖ Out of thirty-nine solutions including all those considered in the present paper, the only one which evolved heat when made was this one composed of resorcinol and ethyl alcohol. Neither formula to be preferred.

* Menschutkin, Ber. d. d. chem. Gesellsch., xv, 1516, 1882.
† Talmadge, Journ. Phys. Chem., i, 547, 1897.
‡ Journ. Phys. Chem. i, 775, 1897.
§ Talmadge, Journ. Phys. Chem., i, 547, 1897.
‖ Journ. Am. Chem. Soc., xviii, 146, 1895. This Journal, x, 449, 1900.

Acenaphthene in propyl alcohol. 7 per cent acenaphthene. Association is indicated. Corrections very large. Neither formula to be preferred.

Naphthalene in propyl alcohol. 10 per cent to 22 per cent naphthalene. The molecular weight is below the normal at 29·8° but the corrections are very large. At 45° association is strongly indicated, though the corrections are too large for this conclusion to be altogether satisfactory. Neither formula to be preferred.

Naphthalene in toluene. 35 per cent to 54 per cent naphthalene. The molecular weights are normal by formula (1) but abnormal by formula (2). Considerable association is indicated by the second formula. The corrections are very small. Formula (1) much to be preferred.

Acenaphthene in toluene. 17 per cent to 45 per cent acenaphthene. The average molecular weight is 151 ± 3 by formula (1) but quite abnormal, 172 ± 5, by formula (2). Association is indicated by the latter formula. The corrections are small. Formula (1) is much to be preferred.

In not a single case then does formula (2) give very satisfactory results, whereas in several cases formula (1) does so and in no case is it less satisfactory than formula (2).

Now formula (1) is altogether too arbitrary. What right have we to use the molecular weight of the solvent in the gaseous state in preference to the molecular weight in the liquid state. In formula (2) the molecular weight in the gaseous state is to be used according to van't Hoff's theory. We have good reason to think that the molecular weight of water in the liquid state is twice or perhaps four times 18. Were we to put some such value for M in (1), the results would be very objectionable. We can, however, justify the normal value for M, that is its value in the vapor state, by adopting a view published some years ago*; namely, that a liquid giving off vapor contains some vapor in the dissolved form, or otherwise expressed, that the simple molecules corresponding to the vapor molecules are formed inside the liquid instead of at the surface. So long as the solvent gives off simple molecules in the vapor state, so long there are dissolved simple molecules in the liquid, and these are the molecules whose concentration is changed by the solute. The complex molecules produce the simple dissolved molecules but have no direct vapor pressure of their own.

Let us consider a liquid consisting of simple molecules only whose vapor pressure is p. To this liquid, equation 3 applies directly. Now suppose that the liquid is mixed with so much of some other inert, non-volatile, liquid that the vapor pressure

* Journ. Am. Chem. Soc., xviii, 724, 1896.

of the mixture is reduced to one-half of p, and let us dissolve in this complex solvent the same quantity of solute as we should have dissolved in the simple solvent in making a molecular weight determination, using the same weight of complex solvent as we should use of simple solvent. Then

$$m = \frac{w\mathrm{M}}{\mathrm{W}} \frac{p'/2}{(p-p')/2} = \frac{w\mathrm{M}}{\mathrm{W}} \frac{p}{p-p'}$$

This is what is supposed to be the case with water or with any other solvent whose molecules are complex. The complex molecules are altogether inert. They play the part of the inert liquid in the above complex solvent, and all we need know is the molecular weight of the solvent in the vapor state.

Put (1) in the form

$$\frac{n}{\mathrm{N}} = \frac{p}{p'} - 1, \quad \frac{n}{\mathrm{N}} + 1 = \frac{p}{p'}, \quad l\left(\frac{n}{\mathrm{N}} + 1\right) = l\frac{p}{p'} \qquad (5)$$

Integrating

$$\mathrm{Q} = \frac{\mathrm{RT}^2}{p} \frac{dp}{d\mathrm{T}}$$

which is the second law of thermodynamics applied to vaporization, and remembering that under these conditions, dp/dt is negative, we get

$$l\frac{p}{p'} = \frac{\mathrm{Q}'}{\mathrm{R}} \frac{\mathrm{T}_1 - \mathrm{T}_0}{\mathrm{T}_1\mathrm{T}_0}$$

Substituting in (5) we have

$$l\left(\frac{n}{\mathrm{N}} + 1\right) = \frac{\mathrm{Q}'}{\mathrm{R}} \frac{\mathrm{T}_1 - \mathrm{T}_0}{\mathrm{T}_1\mathrm{T}_0},$$

where Q′ is the heat of vaporization of one gram-molecule of solvent from the solution, the quantity of solution being so great that no change in concentration is produced when the gram-molecule is removed, T_1 is the boiling point of the solution, T_0 that of the pure solvent, and R is the gas constant.

This equation is available for determining the molecular weights according to the boiling point method or to determine the latent heat of vaporization of the solvent. It will answer for all purposes to which van't Hoff's formula is put and is *altogether independent of the osmotic theory.*

A corresponding equation is easily obtained in terms of heat of fusion and freezing temperatures.

Rutgers College, December, 1901.

CLARENCE KING.

Of the many rapid advances in various branches of science during the last quarter of the past century none has been more remarkable than that of geology. The fundamental cause of this advance is to be ascribed less to the brilliant discoveries and generalizations of individual investigators, of which, however, there has been no want, than to the systematic organization of geological work, which has given a sounder basis for generalization and rendered the work of the individual more effective.

In the earlier days, when only State geological surveys were carried on, and those without adequate maps, no satisfactory correlation of their results was possible; hence much time was often wasted in polemical discussions that might better have been employed in more systematic field observation. A few leading minds like Dana, Hall, Rogers, and others had made brilliant generalizations that left their impress upon the science of geology, but in cases of conflict of opinion the array of facts that could be cited to confirm or deny a given hypothesis was insufficient to produce final conviction.

It was not until the truth, that geological studies cannot profitably be confined within State lines or other artificial boundaries, had been proved by practical demonstration, that the aid of the general government was freely and permanently enlisted, and thereby geological science in America raised to its present high position.

To the accomplishment of this result the late Clarence King was the foremost and one of the most active contributors. It was he whose personal efforts created the 40th Parallel Survey, which was the first government exploration primarily devoted to geological investigation, the first geological survey in the country to make and publish topographical maps as a basis for its geology, the first to employ microscopical petrography in the study of its rocks, and the first to institute systematic geological examinations of mining districts with a view of establishing a more satisfactory theory of vein formation.

The organization of the United States Geological Survey as a permanent bureau of the Government, which naturally resulted from the work of this and succeeding government explorations, was in great measure due to his personal efforts.

It was, however, not as an organizer alone that King contributed to the advance of geological science; his writings have been of the very highest order, not only in their matter but in their manner of presentment; while his personal influence upon fellow geologists and his suggestiveness have

had an effect in raising the standard of geological work in this country, which, while less susceptible of direct estimation, has been none the less real and permanent.

He was a man of remarkable intellectual versatility, and has been probably as widely known and appreciated for his literary as for his scientific ability, though his published literary writings have been singularly few in number. The recollection of his consummate art as a conversationalist and raconteur, of the delicate wit and irrepressible humor that showed itself at times even in his scientific writings, of the kindly spirit and refined courtesy that characterized his every action, and of his irresistibly attractive smile, has left behind a mingled feeling of pleasure and regret among all who had the privilege of knowing him.

Clarence King was born at Newport, Rhode Island, on the 6th day of January, 1842. He was the only son of James Rivers and Florence Little King. His ancestors were among the early settlers of New England, and all, as far as known, of English extraction. Among them were an unusual number of cultivated men, graduates of colleges, or distinguished in the learned professions, in whom can be found traces of the many and varied accomplishments in science, literature and the arts that were so happily combined in their brilliant descendant.

Daniel King, the emigrant, who came to Lynn, Massachusetts, in 1637, was a younger son of Ralphe Kinge of Watford, Hertfordshire, England. His great-grandson, Benjamin, moved from Salem, Massachusetts, to Newport, Rhode Island, and, according to family tradition, was a man of scientific tastes, who occupied himself with philosophical instruments and assisted Benjamin Franklin in his early experiments in electricity. Samuel King of Newport, son of the latter and great-grandfather of Clarence, was a portrait painter of merit, who numbered among his pupils Washington Allston, and Malbone, the miniaturist. On his mother's side, one of King's great-grandfathers, William Little, was a graduate of Yale in 1777, and received an honorary degree from Harvard in 1786. Another, Ashur Robbins, graduated from Yale in 1772, was United States Senator from Rhode Island 1825–39, and received the degree of LL.D. from Brown in 1835. His grandfather, William Little, Jr., who died early in life, was noted as a linguist and a scholar. His grandmother, Mrs. Sophia Little, poet and philanthropist, was a woman of remarkable public spirit, energy, and decision of character, who retained her mental and physical vigor in most remarkable degree up to the time of her death in 1893, in her 95th year.

His immediate King ancestors were pioneer merchants in the then highly remunerative China trade, his grandfather,

Samuel Vernon King, having been as early as 1803 a partner in the commercial house of Talbot, Olyphant & King. Four of the latter's sons succeeded him in that business, the house later becoming known as King & Company. James, the second son, married at the early age of 21, and was obliged to leave his young wife before the birth of his first child, Clarence, in order to take the place of his elder brother in China. By a singular fatality, three out of the four brothers died in the far East, and the house of King & Company became bankrupt during the crisis of 1857 through the loss of one of the company's steamers, which, under the charge of a confidential English clerk (also named King) was carrying a large amount of specie to meet their liabilities at another port. In this disaster was involved the property of James, which had remained in the firm since his death at Amoy, China, in 1848.

The young mother, left a widow at 22, devoted herself to the education of her only son, learning with an inherited facility both classical and modern languages that she might teach them in turn to him, and thus was founded a close, intellectual companionship which lasted until his death.

King's early boyhood days were spent at Newport, but he received his principal school education in the endowed high-school at Hartford.

As a very young child he showed symptoms of a decided bent toward the study of natural phenomena, which was further developed during long summer vacations, spent in fishing, hunting and botanizing in the Green Mountains.

In 1859 he became a member of the Sheffield Scientific School, and during the two following years acquired a systematic grounding in the sciences of geology and mineralogy under the inspiring teachings of James D. Dana and George J. Brush, at that time their foremost exponents. Among his fellow students who have since become eminent in their respective professions were O. C. Marsh, Arnold Hague and Samuel Parsons. He graduated in 1862 with the degree of B.S., being among the first students of the Scientific School to receive a degree from the faculty of Yale College.

During his college course, he was a leader among his mates in athletic sports, as well as in study of nature, being captain of a base-ball team and stroke oar of a racing crew.

During the winter following his graduation, he was, for a time, a student of glaciology under Agassiz, and later became a devotee of the Ruskinian schools of art study under the leadership of Russell Sturgis.

In May, 1863, in company with his life-long friend, James T. Gardiner, whose health had broken down under too close devotion to his studies, King started on a horseback trip across the

Continent. Upon reaching St. Joe, Missouri, then the western limit of railroad communications, they were invited to join the party of a well-to-do emigrant family, whose favor King had unconsciously gained by his characteristically tender care for their children during the latter part of the railroad journey. Their line of march followed, in general, what was known as the Old Fremont route, up the North Platte river and down the Humboldt river in Nevada. The rate of travel of such a party was necessarily very slow, and the young explorers, being mounted on good horses of their own, were able to make excursions into the neighboring mountains for the purposes of exploration and study, which, owing to the hostility of the Indians, were not always without danger.

After having crossed the deserts of Nevada, they left the party to visit the then famous Comstock Lode. On the night of their arrival in Virginia City, the house in which they were staying caught fire and all their belongings were lost. Nothing daunted, King went to work at days' wages in a quartz mill to earn sufficient funds to enable them to continue their journey. In a few weeks they started again, crossing the Sierra Nevada on foot, and proceeding by boat from Sacramento to San Francisco. On this trip an incident which led to their making the acquaintance of Prof. William M. Brewer, then assistant on the Geological Survey of California, proved to be the turning point in their careers.

King's professional work as a geologist may be said to have commenced with his acceptance of the position of volunteer assistant geologist on the Geological Survey of California under Prof. J. D. Whitney. During the three years that this connection lasted the work was largely exploratory, for as yet even the geography of the country was but imperfectly known. It thus gave full scope to the enterprise, energy and powers of endurance that characterized him during his whole life. In spite of his youth, he soon became a leader, especially in the exploration of the high mountain mass of the southern Sierras discovered by him, whose highest peak, Mt. Whitney, still holds the palm as the highest point within the United States (excluding Alaska). During the winter of 1865–6 he also made an exploration of the desert regions of southern California and Arizona as scientific aide to General McDowell, which involved much hardship and no little danger.

Of even more importance for his future work was the familiar knowledge of the different varieties of volcanic rocks, acquired during field studies around the extinct volcanoes of the northern Sierras and in association with his friend Baron von Richthofen, and in which for many years he stood preëminent among geologists of his time.

King's earliest scientific achievement on the Survey was the discovery, during the study of the gold mines of the Mariposa estate in 1863, of fossils in the highly metamorphosed slates of the gold belt of California, a discovery that solved the problem of their age which had long puzzled western geologists.

In the autumn of 1866, after his return to the east, he judged that political conditions were then most favorable for the realization of a plan that had gradually been shaping itself in his mind ever since he first crossed the continent, viz: that of connecting the geology of the east with that of the west by making, under government auspices, a survey across the whole Cordilleran system at its widest point.

There had been considerable apprehension during the dark days of the Civil War lest California, physically isolated as she was at that time, should separate from the other states and set up an independent government. The subsidizing of the Transcontinental railroads was the first step towards overcoming this isolation and binding her more closely to the East. In King's judgment a second, hardly less important one, would be the development of the mineral resources of the country thus to be opened up; and this could best be accomplished by making a thorough geological survey of that region.

During the winter of 1866–7, which he spent at Washington, he was so successful in impressing this view upon Congress, that not only was a generous appropriation voted for the geological exploration planned, but King himself was placed in absolute charge of it, subject only to the administrative control of General A. A. Humphreys, Chief of Engineers.

In these days, when the West is covered by a network of railways, it is difficult to conceive the obstacles that had to be encountered at that time in carrying out so ambitious and, as some then thought, so chimerical a plan as that which King had conceived. Of the Transcontinental roads, but a few miles at either end had yet been constructed. The territories of Utah and Nevada were represented on most maps of the day as one broad desert, and it was doubted whether sufficient water and grass could be found there to support a camping party. Everything had to be specially created for the purpose, and, after the party had reached California over the Panama route, it took three months to prepare the necessary camp outfit and to carry them to their field of work. Even after this work was well under way there were times when it seemed that obstacles ahead were almost too great to be overcome, but King's energy and resourcefulness were equal to every emergency, and he soon succeeded in inspiring all of the members of his party with such confidence in his leadership and in imparting to them such measure of his own enthusiasm that they never faltered in their devotion to the work, even though

the three years originally planned were subsequently extended, by the unsolicited action of Congress, to seven.

In recognition of the legitimacy of the public demand for a direct application of the results of government geological work, King pushed first to completion a scientific study of the ore deposits of the region surveyed; more particularly of the great Comstock Lode, whose enormous silver product was then disturbing the monetary system of the country. This work, written conjointly by himself and James D. Hague, appeared as early as 1870 under the title of "Mining Industry." It was described by one of its most capable critics as "by itself a scientific manual of American precious metal mining and metallurgy." It is considered classic among works in its line and has served as a model for similar monographs which have since been published under government auspices and done so much to raise the mining industry of America to its present high position.

In 1870 he discovered on the slopes of Mt. Shasta the first actual glaciers known to exist in the United States; and in their study made observations that are credited with first suggesting the true origin of the kettle-holes and kames of New England. His later discovery in the summer of 1874, that a line of islands along the southern coast of New England were a part of its terminal moraine, had much influence in inducing the later systematic studies of the Continental glacier.

The field work of the Survey was completed in 1873, but it was 1877 before the respective specialists had been able to work up the amount of material gathered, for it was one of King's fundamental principles that abundant collections should be made in the field to illustrate all the natural phenomena observed, and the lithological collections alone numbered about five thousand specimens.

In 1874, he sent one member of his corps to Europe to study the methods of European geological surveys and to obtain the best and latest geological literature with which at that time American libraries were but scantily provided. He, also, instructed him to confer with Prof. Zirkel, then the greatest microscopical petrographer of the day, and to induce him, if possible, to visit America and study in the presence of the collectors their collection of rock specimens, for at that time no American geologist had any practical knowledge of this new branch of geology. From this visit resulted Zirkel's volume on microscopical petrography, which marked the opening of a new era in geological study in the United States.

King reserved for himself the final summarizing of the work of his assistants and the drawing of general conclusions and theoretical deductions therefrom. This he wrote in the

winter of 1877–8, and published in a quarto volume of more than 800 pages under the title of "Systematic Geology." It has been characterized as the most masterly summary of a great piece of geological field work that has ever been written, and is used to this day by university professors of geology as a model for their advanced students.

King's crowning service to geological science in America followed shortly after the completion of the 40th Parallel work. After two of his field seasons had demonstrated the practicability of geological map-making in the west, the Wheeler Survey was inaugurated under the Engineer Department of the Army, and the already existing Hayden Survey later adopted his example in making topographical maps as a basis for its geology, employing for this purpose the 40th Parallel topographers after their term of service in the latter Survey had expired. The work of these two organizations became so popular that each desired to cover the whole of the unsurveyed area in the west, and their rivalry in time became so intense that the influence of either party with Congress was used to curtail the appropriation allotted to the other. As a final result of this rivalry the time came when there was serious danger that all government aid for geological work would be cut off. It was mainly through King's influence among the leading scientific men of the country and his tactful management of affairs in Congress that this crisis was averted. The question was referred to the National Academy of Sciences, and their recommendations, which were on lines laid down by him, were finally adopted by Congress, and on March 3, 1879, a law was passed establishing the United States Geological Survey as a bureau of the Interior Department. President Hayes, after consultation with the best scientists of the country, appointed Clarence King as the first director of the new Bureau. King accepted the appointment with the distinct understanding that he should remain at its head only long enough to appoint its staff, organize its work, and guide its forces into full activity. At the close of Hayes' term, he offered his resignation, but at the President's request, he held over until after the inauguration of Garfield. The latter accepted it, on March 12th, 1881, in an autograph letter, expressing in the warmest terms his appreciation of the efficiency of King's service and his regret that he did not find it possible to remain longer in charge of the Geological Bureau.

Brief as was the duration of his administration, his influence, being exercised at the critical period of the Survey's existence, left a lasting impress upon it. He outlined the broad, general principles upon which its work should be conducted and its subsequent success has been in a great measure dependent upon

the faithfulness with which these principles have been followed by his successors.

Foreseeing the important part that the development of its mineral resources was destined to play in the future progress of the country, he judged that, while not neglecting the more purely scientific side, its work should be primarily devoted to the direct application of geological results to the development of these resources. It has been because the people at large have realized its practical success in this line that the Survey has been more richly endowed, and thus better able to carry on its purely scientific work, than any organization of its kind in the world.

King set the very highest standard for its work, and showed remarkable judgment and knowledge of character in his selection of the men who, in their respective branches, were best fitted to keep it up, as nearly as possible, to this standard. In his establishment of a physical laboratory for the determination of the physical constants of rocks, he took a step in the direction of the application of methods of exact science to geological problems so far in advance of the average standards of the day that its importance was not generally realized until long after.

In all his after life, he maintained a lively interest in the work of the Survey, and kept closely in touch with his successors in office, who frequently consulted him on important questions of policy.

After his retirement from government service, he came much less frequently into personal contact with scientific men, for he had little sympathy with that phase of scientific activity which is represented by academies and societies.

He had been elected a fellow of the Geological Society of London in 1874, and of the National Academy of Sciences in 1876. He was, also, a life member of the American Institute of Mining Engineers, but he rarely attended the meetings of any of these associations and never contributed to their proceedings. He found his recreation from business occupations rather in social intercourse with his many friends and admirers in the literary and artistic world, yet he was not forgetful of his chosen profession, and through all the varied occupations of an intensely busy life he still continued his investigations into the deeper problems of geology, to carry on which had been one of his motives for giving up administrative duties on the Geological Survey.

In his financial affairs, King had difficulties to contend with that few of his friends realized, and which would have completely discouraged a man of less sanguine and buoyant temperament.

At two successive periods in his youth, those to whom he would naturally have looked for financial support were overwhelmed by commercial disaster, leaving him to provide not only for his own wants but for those of other members of his family. In his later life circumstances entirely beyond his control more than once baffled or annulled the efforts he was making to establish himself on such a financial basis that he would feel justified in applying his entire time to his chosen pursuits in science and literature. He was consequently obliged to devote more of his time and energy to the directly remunerative side of his profession—that of the mining engineer—than he otherwise would have done. This was especially true of his later years, though even in earlier life his services had been not infrequently sought in cases of great moment.

He owed his prominent position in this profession not alone to his ability and experience as a geologist, which exceeded that of most of his fellow workers, but to his high standard of personal integrity and the rapidity and acuteness of his judgment. These qualities were early illustrated in an incident which gave him perhaps greater prominence in the financial world than any act of his life—his exposure of the diamond fraud of 1872. An apparently well authenticated discovery had been made of diamonds in sufficient quantity to affect the diamond markets of the world. Although its position was kept carefully concealed, through the intimate knowledge of the country possessed by his assistants, King was enabled to determine that it must be located in an area already surveyed by them, and at once fitted out a party to examine it. When this examination, undertaken primarily in the interest of science, had proved that the alleged discovery was an elaborate and skilfully planned fraud, it was his prompt action and unshakable integrity alone that averted a financial disaster which threatened to rival that of the Mississippi Bubble of Law.

In the many important mining suits in which he served as scientific adviser, and which involved most difficult and complicated problems of geological structure, combined with their still more difficult interpretation under the terms of the United States mining laws, he was generally intrusted with the legal as well as the scientific management of the case. As he made it a practice to never trust the eye of another, but to verify every fact by his own personal observation, he obtained such a thorough knowledge of his subject that the most skillful lawyers were unable to shake his testimony by their cross-examination.

In his examination of mines, he visited almost every part of the American continent, and thus acquired a personal familiarity with deep-seated phenomena that it seldoms falls to the lot of a geologist to obtain. Hence he was exceptionally well

equipped in this, as in other respects, to carry on the investigations he had undertaken into the problems of the interior of the earth.

In 1890, Brown University conferred upon him the honorary degree of LL.D. That he received no public recognition of his later scientific work may perhaps be ascribed to its peculiarly unobtrusive character, which gave rise to the erroneous impression that he had abandoned science altogether.

It is difficult to fairly judge King's scientific publications in the light of the present day, for they were written just before the opening of an era of great change in the methods of geological investigation, a change which has thus far proved destructive rather than constructive in its results. Many of the fundamental theories of geology which prevailed at that time have been disproved or abandoned, while as yet there is no general acceptance of those which have been put forward to replace them.

In June, 1877, he delivered the address at the 31st anniversary of the Sheffield Scientific School on "Catastrophism and the Evolution of Environment." It was a protest against the extreme uniformitarianism of that day, based largely on the geological history of the Cordilleran System as developed during the work of the 40th Parallel Survey. This uniformitarianism he characteristically described as "the harmless undestructive rate (of geological change) of to-day, prolonged backward into the deep past." He contended that while the old belief in catastrophic changes had properly disappeared, yet geological history, as he read it, showed that the rate of change had not been so uniform as was claimed by the later school. While a given amount of energy must evidently be expended, he reasoned, to produce a given effect, yet the expenditure of this energy might be extended over a very long time, or crowded into a comparatively short one; and his observations showed him that at certain periods in geological history, the rate of change was accelerated to such a degree that the effect upon life produced was somewhat catastrophic in its nature.

Of his great work upon systematic geology, the larger part —that which outlines the geological history of the Cordilleran System—stands as firmly to-day as it did when written, as a correct and authoritative exposition. In view of the circumstances under which the field work was orginally done, its essential correctness, even in matters of minor detail, is considered surprising by those who have since had occasion to make detailed studies of portions of the area covered.

In the more theoretical sections, while he necessarily did not take into account the great number of new facts which have

been established by more recent work, especially in the domain of microscopic petrography, he showed such grasp of his subjects, and such originality and power of thought, that his views constituted not only an important advance over those of the day, but they were suggestive of the lines of investigation that have been most fruitful in the modern advance of geological science.

For instance, in his discussion of the reason for the changes from acid to basic eruptives within the individual groups, which he proposed as a variation from the natural order in age of volcanic rocks, as laid down by Richthofen, he advanced views very suggestive of the modern conception of differentiation in eruptive magmas.

Again, in endeavoring to account for the formation of those types of granite that pass into gneiss and crystalline schists of essentially the same chemical composition, but which show no evidence of having been subjected to such excessive heat as would produce actual liquefaction, he called in the agency of the immense pressure to which such rocks would necessarily have been subjected. While the long years of combined field work and microscopic study of modern petrographers, made since King's theory was enunciated, have proved that the structure of crystalline schists *is* due to pressure, they do not go so far as he did in assuming that the end product of such mechanical pressure might be granite.

Perhaps his most enduring theoretical discussion of that time was that on hypogeal fusion, in which, accepting the validity of the physical arguments against the fluid interior of the earth, he discusses and rejects Hopkins' theory of residual lakes and Mallett's conception of local lakes produced by mechanical crushing. He then advances an hypothesis of his own which may be called that of a critical shell, or *couche*, between the permanently solid interior and the outer crust of the earth, which is above the temperature of fusion but restrained from fusion by pressure. In this, therefore, the opposing forces of pressure and temperature hold themselves reciprocally in equilibrium, but when this equilibrium is disturbed, as for instance, by a sudden change of the relative position of isobars and isotherms—say by local erosion and rapid transfer of load within limited areas—local lakes of fusion would be created. Iddings, in his "Origin of Igneous Rocks," says of King's treatment of this subject: "By the breadth of his treatment and by better and fuller data he advanced the problem of the origin of the various kinds of volcanic rocks far beyond the point reached by any of his predecessors."

In his chapter on Orography, King says, in speaking of the causes of crust motion: "I can plainly see that were the critical shell established its reactions might thread the tangled

maze of phenomena successfully, but I prefer to build no farther until the underlying physics are worked out." He was at that time already very strongly impressed with the imperfection of the then existing knowledge of terrestrial thermo-dynamics and the indispensability of more exact data in this branch of science for a rational discussion of the fundamental problems of geology.

This idea found a practical outcome a few years later in the establishment of a physical laboratory, immediately after his assumption of the Directorship of the United States Geological Survey. His earnestness and energy is shown by the fact that instead of waiting for the slow action of Congress, he defrayed the cost of the delicate apparatus necessary for this work out of his own pocket. The credit of the brilliant physical investigations carried on in that laboratory is naturally due to Professors Barus and Hallock, who conducted them, but it was King's acumen and good judgment that was responsible for their selection, and his action that made it possible for them to carry on their work. To himself, as he says ten years later in his paper on the Age of the Earth (this Journal, vol. xlv, Jan. 1893), he reserved the privilege of "making geological applications of the laboratory results." The experiments on the physical constants of rocks contemplated were to be directed to the determination (a) of the phenomena of fusion, (b) of those of elasticity and viscosity, and (c) of those of heat conductivity, each considered with special reference to their dependence on temperature and pressure.

The paper on the Age of the Earth, mentioned above, is his only published result, and was but an earnest of what he had planned to do. This was an attempt to advance to new precision Kelvin's estimate of the earth's age deduced from terrestrial refrigeration. It consists mainly of a mathematical discussion of the earth's thermal age as determined from various postulates presented by Laplace, Geo. H. Darwin, and Lord Kelvin, and based on Barus' determinations of the latent heat of fusion, specific heat, melted and solid, and volume of expansion between the solid and melted state, of the rock diabase. This is followed by a critical examination of other methods of determining the earth's age—by tidal retardation, by sun-age, and by variations of eccentricity. After a careful scrutiny of all the data on the effect of pressure on the temperature of consolidation, King concluded that, without further experimental data, "we have no warrant for extending the earth's age beyond 24 millions of years," an estimate which, as the result of a somewhat more extended discussion, was afterwards confirmed by Lord Kelvin himself. (Smithsonian Report, 1897, p. 345.)

His further investigations along the same general lines on the fundamental principles of upheaval and subsidence were in an advanced stage of completion when they were cut off by his untimely death.

It is practically impossible to adequately characterize King's literary work, for the greater part of what he did was never published, and very likely never even written. It was his habit to work out in his head any subject which interested him, even down to its minutest details, before putting a pen to paper; once this was accomplished to his satisfaction, he wrote with such ease and rapidity that the words actually flowed from his pen. Probably one reason that he did not write more was that his own literary taste was so refined and exacting that he was never thoroughly satisfied with his own conceptions. In his scientific writing, there was generally some imperious necessity that made it urgent upon him to give his results to the public in spite of the imperfections he might still see in them, but in literature such necessity rarely appeared. What he did publish he himself held in comparatively light esteem, but in the opinion of the best literary writers of the day, with most of whom he was on terms of friendly and intimate intercourse, his writings, and even more his affluent and delightful talks, disclosed a literary quality that might have given him a foremost place among American men of letters.

His one literary book, "Mountaineering in the Sierra Nevada," went through more editions in England than in this country and was very generally regarded there as far the best book of its kind that had ever been written. It was primarily a series of articles giving an account of his early experiences in California among the mountains that he loved so well and the peculiar people that he met. He undertook it, he once said, as an experiment to see if it were possible to write scenic description in such a way that the general public would read it.

Of his occasional articles in current periodicals, two appeared in the Century in 1886, and three in the Forum. Of the latter, two on Cuba, published in the years immediately preceding the Spanish War, were written under the impulse of strong feelings of sympathy with the cause of the insurgents, with whom he had come into intimate personal contact during a winter spent on the island at the country house of a friend.

Of his Century articles, one was a delicate tribute to his closest friend, John Hay, as one of the biographers of Lincoln; the other, a short sketch of his search for the "Helmet of Mambrino" for a fellow Cervantista, was that which more than anything he ever published disclosed the exquisite deli-

cacy of his literary touch, which rivaled that of Howells or James, and an even rarer quality of wit than Bret Harte's.

King was a man of remarkably robust physique, and showed throughout his physically arduous life powers of endurance that are rarely equaled; yet it was one of the penalties of the highly sensitive and nervous organization, which rendered possible his marvelously acute and delicate perception, that he was subject to sudden and almost unaccountable break-downs in which he suffered intensely. His last severe illness was an attack of pneumonia in the early part of 1901, which followed an examination of a mining property during very inclement weather. From this he recovered, but tuberculosis, the seeds of which were supposed to have been sown during a trip to the Klondike during the previous summer, made such rapid progress during the following months that, after several changes of climate in the vain hope of ameliorating his condition, he finally passed away, quietly and without suffering, on the 24th day of December in the year 1901.

It was part of his characteristic unselfishness that he effectually discouraged all offers on the part of friends and relations to visit him—visits which might have cheered his last lonely days in that far distant region.

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SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Manufacture of Sulphuric Acid by the Contact Process.*—In an address before the German Chemical Society Knietsch has given an interesting account of the development of a method for the manufacture of sulphuric acid which is evidently destined to revolutionize this great industry, in supplanting the use of the old lead-chamber method. Since 1831, when Phillips in England discovered the fact that sulphur dioxide and oxygen can be made to combine in contact with finely-divided platinum, many efforts have been made to apply this and other catalytic agents to the practical manufacture of sulphuric acid, but until within a few years the problem has remained unsolved. The success of the process at the "Badische Anilin- und Soda-Fabrik" has been due to a long series of carefully conducted experiments. A serious obstacle encountered was the difficulty of properly purifying the gases from the pyrites-furnaces so that they would not quickly destroy the activity of the platinum, which is used in the form of platinized asbestos. Traces of arsenic were found to be one of the chief causes of this trouble, and by proper cooling and washing, and by actually filtering the gases it was finally possible to remove all solid particles, so that the platinum remained effective for an unlimited time. It was found that a temperature of about 450° C. is most favorable for the reaction, hence instead of heating the platinized asbestos, as was formerly thought necessary, it has been found desirable to cool it after the process has been started. The fact that the mass action of an excess of one of the reacting gases has an important influence upon the completeness of the reaction was discovered; hence the reaction is practically complete with the gases from pyrites burners containing about three times the necessary oxygen. The process is particularly adapted to the manufacture of fuming sulphuric acid and the anhydride, but there can be little doubt that it will be the method of the future for the production of the ordinary acid. The statement is made that the production of sulphuric anhydride by this process at the "Badische" works amounted to 116,000 tons in the year 1900. The address as published gives many valuable data in respect to the physical properties of all strengths of sulphuric acid, including the melting-point, specific-gravity, specific heat, heat of solution, electrical resistance, action on iron, boiling-point, vapor-pressure, viscosity, and capillary action.—*Berichte*, xxxiv, 4069. H. L. W.

2. *Metallic Carbides.*—Moissan has recently published a review of the present knowledge of this subject, to which he has been the most prominent contributor. The following carbides are not decomposed by water: Fe_3C, Cr_3C_2, Cr_4C_3, Mo_2C, WC, W_2C, VC, ZrC, and TiC. The iron carbide, Fe_3C, exists in

steel. It may be prepared by heating the components to 3000° in the electric furnace and pouring the mass into water. Diamonds are formed where great pressure exists in the interior of the regulus, and well crystallized Fe_3C can be separated from the product by dissolving the metallic iron in dilute acid. If the product be slowly cooled, the greater part of the carbon separates as graphite and ordinary cast-iron results. The carbides of chromium, molybdenum, tungsten, vanadium, zirconium and titanium are all well-crystallized substances produced by means of the electric furnace, and in general they are very stable in their behavior with acids, etc.

The carbides which are decomposed by water are, Li_2C_2, K_2C_2, Na_2C_2, CaC_2, SrC_2, BaC_2, CeC_2, LaC_2, PrC_2, NdC_2, SaC_2, YC_2, ThC_2, Al_4C_3, Be_2C, Mn_3C and U_2C_3. Sodium and potassium carbides are prepared by the action of acetylene gas upon the metals. They are decomposed at high temperatures, hence they cannot be prepared by the electric furnace method. On the other hand, the other alkali-metal, lithium, forms a carbide at high temperatures. This is transparent and well crystallized. The alkali-metal carbides and also those of calcium, strontium and barium yield acetylene, C_2H_2, when they are treated with water. It is calcium carbide which is extensively used for the preparation of this gas. The commercial product is dark in color from impurities, but when pure it is transparent and colorless. Aluminum and beryllium carbides can be prepared by means of the electric furnace; both of these give methane, CH_4, with water, according to the following equations:

$$Al_4C_3 + 12H_2O = 3CH_4 + 4Al(OH)_3$$
$$Be_2C + 4H_2O = CH_4 + 2Be(OH)_2.$$

The carbides decomposable by water, that have been mentioned, give off a single gas, either acetylene or methane, when thus decomposed, but the others produce more than one product. Manganese carbide gives methane and hydrogen as follows:

$$Mn_3C + 6H_2O = CH_4 + H_2 + 3Mn(OH)_2.$$

Uranium carbide gives a mixture of acetylene, ethylene, methane and hydrogen; cerium and lauthanum carbides give mixtures of acetylene, ethylene, methane, and some liquid and solid hydrocarbons; yttrium, neodymium, praseodymium, samarium, and thorium carbides give acetylene, methylene and methane, and in some instances hydrogen also.

Certain metals, such as gold, bismuth, and tin, dissolve no carbon in the electric furnace, while copper dissolves very little. Silver dissolves some carbon at the temperature at which it evaporates, but most of this separates upon cooling. The platinum metals dissolve carbon readily at high temperatures, but it separates as graphite when the metals solidify.

Moissan advances the theory, somewhat similar to one proposed by Mendeléeff many years ago, that petroleum, in some instances, has been produced from carbides. He believes that

formerly all the carbon in the earth existed in the form of carbides, and that these have been gradually decomposed by the action of water.—*Zeitschr. für Electrochem.*, viii, 44. H. L. W.

3. *Potassium Hydride.*—It has been found by MOISSAN that the action of hydrogen upon metallic potassium at 360° gives a white compound which sublimes in crystals and has a composition corresponding to the formula KH. The substance is exceedingly sensitive to the action of moisture, and it takes fire at ordinary temperature when exposed to fluorine, chlorine or dry oxygen. It seems probable that Gay-Lussac and Thenard's supposed compound K_2H was a mixture of the true hydride with metallic potassium, since Moissan has found that the action of hydrogen on potassium is very slow.—*Comptes Rendus*, cxxxiv, 18. H. L. W.

4. *On Electrical Conductivities produced in Air by the Motion of Negative Ions.*—Professor TOWNSHEND (Phil. Mag., Feb., 1901) has shown that negative ions produced in a gas are capable of disintegrating other molecules by collision, and thus of generating other ions. This subject has been further studied by P. J. Kirkby, whose experiments confirm Professor Townshend's general result, who finds that there is a remarkable difference in the behavior of positive and negative ions when moving in a small pressure under electric force. The negative ions have the property of disintegrating other molecules when colliding with them, while the positive ions do not appear to have this property. Professor J. J. Thomson has found from experiments with ultra violet light the mass of the negative ion to be 3×10^{-26} of a gram. Professor Townshend finds $4{\cdot}5\times10^{-24}$ as the weight of a molecule of hydrogen. This makes $6{\cdot}6\times10^{-23}$ as the corresponding weight for air, which is more than three times the number given by Meyer (Kinetic Theory of Gases, art. 121). If it is assumed that the negative ions produced by the Röntgen rays are identical with those produced by ultra-violet, the molecules of air are 2200 times the size of the negative ion according to the above numbers. If the positive ion is what remains after the negative ion is detached from it, it follows that the positive ion does not materially differ in mass from the ordinary molecule in air. It far exceeds in magnitude the negative ion, and the mean path of the latter exceeds that of the former. Professor Townshend finds $\cdot47^{mm}$ as the path of the negative ion in 1^{mm} pressure of air. The corresponding path of the positive assumed to be equal to that of the molecule of air is about ·094 of a millimeter. This must be multiplied by $\sqrt{2}$ when the ion is moving under electric force.—*Phil. Mag.*, Feb., 1902, pp. 212–225. J. T.

5. *On a kind of Radio-activity imparted to certain Salts by Cathode Rays.*—Dr. J. C. MCLENNAN gives in this paper an account of a research which shows that certain salts which show no radio-activity as ordinarily prepared exhibit this property in a very marked manner on being gently heated after exposure to cathode rays. The radiation emitted was sufficient to discharge

positively electrified bodies but not negatively electrified ones, and could not impart a charge to an unelectrified body. A list of the substances is given together with an account of the instruments employed. The author thinks it probable that the salts on being heated emit a stream of negatively charged particles or corpuscles, which are drawn to the positively charged gold leaf of the electrometer by the electrostatic field and thus discharge it.—*Phil. Mag.*, Feb., 1902, pp. 195–203. J. T.

6. *Radio-active Bodies.*—M. P. CURIE and Madame S. CURIE show that in uranium, thorium, radium, and probably actinium, the radio-activity remains constant, if the chemical and physical states of these substances remain unchanged. Polonium, however, appears to be an exception to this rule.—*Comptes Rendus*, Jan. 13, 1902. J. T.

7. *Outlines of Electrochemistry;* by H. C. JONES. Pp. 106, 8vo. New York, 1901 (The Electrical Review Publishing Co.).—The volume consists of a series of articles published previously in the Electrical Review. The author has aimed, apparently, to present the subject of electrochemistry so that it could be understood by any one with a moderate knowledge of chemistry, and we believe he has succeeded most admirably. His chapters on electromotive force are particularly good. The same may be said of the chapters relating to the conductivity of solutions and the velocity of the ions. We wish that Professor Jones had extended the chapters on electrolysis somewhat, so as to include more of the technical applications. H. W. F.

8. *Die Chemische Organisation der Zelle.* Ein Vortrag von FRANZ HOFMEISTER. Pp. 29. Braunschweig, 1901. F. Vieweg und Sohn. Mk., 0.60.—Most writers on the functions of the living cell have built up their theories on the basis of purely morphological considerations. In this lecture, intended for the meeting of German Men-of-Science at Hamburg, Professor Hofmeister points out that the biological processes of cells are mostly chemical in nature and that therefore a new standpoint must be assumed before further advances in our understanding of these processes can be made. Even the modern physiological study of elementary organisms does not promise to throw much light on the problems involved. For protoplasm is no simple mechanical structure; its activity is rather dependent upon the chemical elements involved therein, and these are present in all their complexity in even the simplest forms of life. The author attempts to tell us what must be the make-up of the living cell in order that protoplasm—the functions of which are chemical—may accomplish its work. The manifold reactions of liver cells are selected to show how the cell is in reality a well-equipped chemical laboratory. Hydrations, oxidations, reductions, condensations,—all are accomplished through the activity of catalytic agents, colloidal in nature, which are the important agents in the chemical transformations of the cell. The rôle of the intracellular enzymes, reversible in their action, is thus presented in a new

light. The possible significance of individual peculiarities in morphological structure is also considered in this connection.

Professor Hofmeister concludes by pointing out that the consideration of the cell as a machine equipped with chemical and physico-chemical accessories does away with the necessity of calling upon other than well known forces for an explanation of the work done. There is to-day no occasion to set up the doctrine of "Ignorabimus," or to assume the existence of some additional, indefinite, *vital* force. L. B. M.

9. *Beitraege zur Chemischen Physiologie und Pathologie*, herausgegeben von FRANZ HOFMEISTER. I. Band, 7/9 Heft. Braunschweig, 1901 (F. Vieweg und Sohn). — This number of the Beitraege includes the results of an elaborate chemical study of the active constituents of "immune" sera, by Dr. E. P. Pick of Prag; and five investigations of physiological-chemical interest, from the laboratory of Professor Hofmeister in Strassburg. Among the latter are contained demonstrations of the existence of phenyl-analin as a constituent complex in the proteid molecule, as indicated by the preparation of cinnamic acid from the decomposition products (by Ducceschi and Spiro); a study of the transformations of albumoses by the gastric mucosa (Glaessner); and an investigation suggesting the preëminent importance of the liver for the synthesis of aromatic ethereal sulphates in the animal body (Embden and Glaessner). In the same number Wróblewski and his co-workers have brought new evidence of the destructive action of certain enzymes upon one another.

Heft 10/12. The ten contributions in this number cover too many departments of chemical physiology to receive detailed mention here. Attention may be called, however, to the discovery of oxyphenylethyl-amine as a product of pancreatic digestion (Emerson) and to two papers on the proteid chemistry of plants. (Iwanoff; Czapek.) Nine laboratories are represented. A survey of the table of contents of the first volume of the Beitraege, just completed, will, in our opinion, justify the promise previously expressed by the reviewer, that the new journal has a future of usefulness. L. B. M.

II. GEOLOGY AND NATURAL HISTORY.

1. *On the occurrence of Chrompicotite in Canada;* by G. CHR. HOFFMANN, of the Geological Survey of Canada. (Communicated by permission of the Director.)—This variety of chromite—a mineral hitherto found in but one locality, namely, at Dun Mountain, in New Zealand—has been somewhat recently met with, in considerable quantity, in veins or dikes in the volcanic series of the Miocene Tertiary, on Scottie Creek—a stream flowing into the Bonaparte—about nine hundred feet west of its first tributary on the south side and some seven miles east of Mundorff, in the district of Lillooet, province of British Columbia.

The mineral, which is massive, with a fine to somewhat coarse granular structure, is associated with a pale yellow serpentine,

small quantities of white to grayish-brown quartz and of white felspar, and a very small quantity of a green chromiferous silicate. It has a velvet-black color, and is opaque ; in very thin sections, however, it is translucent, and brownish-red by transmitted light. The luster is submetallic. It breaks with an uneven fracture ; is very brittle; and affords a grayish inclining to blackish, brown streak. It is non-magnetic. Its specific gravity, at 15·5° C., is 4·239. Before the blowpipe, both in the outer and inner flame, it remains unchanged. With borax, it gives a bead which, in the oxidizing flame, is yellow while hot, and pure green when cold ; and in the reducing flame, is of a fine emerald-green color, both hot and cold. With salt of phosphorus it yields a limpid glass which, in the oxidizing flame, while hot, appears yellowish, and on cooling, assumes a fine green color ; whilst in the reducing flame, the bead is greenish while hot, and bright emerald-green when cold. It is not acted upon by acids.

The mean of two very closely concordant analyses, conducted by Mr. R. A. A. Johnston, showed this mineral to have the following composition :

Chromium sesquioxide	55·90
Alumina	13·83
Ferrous oxide	14·64
Magnesia	15·01
Silica	0·60
	99·98

The presence of the silica would indicate that, notwithstanding the great care exercised by Mr. Johnston in the preparation of the material employed by him for analysis—a matter attended with considerable difficulty, even with the aid of heavy solutions—the same was, nevertheless, not absolutely free from all traces of some of the associated minerals.

2. *Still Rivers of Western Connecticut ;* by WILLIAM HERBERT HOBBS. Bull. Geol. Soc., vol. xiii, pp. 17–26, pls. i–ii.—In this paper two rivers, viz. : Still River between Danbury and New Milford and Still River at Winsted, are described and their life history traced.

3. *Petrographisches Praktikum ;* by R. RHEINISCH. Erster Theil : Gesteinbildende Mineralien. Pp. 135, 8vo, 82 figs. in text. Berlin, 1901 (Gebr. Borntraeger).—The author states in his preface that this work is intended for those who desire only a general knowledge of the subject or wish to take it up by themselves. After a preliminary description of the making of thin sections and the microscope, the various important rock-making minerals are treated, with the introduction when necessary of optical or chemical means of discrimination. The work presupposes some knowledge of mineralogy, optics and chemistry. It is designedly of elementary character, for the use of beginners, and in this field should prove useful. L. V. P.

4. *The Grasses of Iowa;* by L. H. PAMMEL, J. B. WEEMS and F. LAMSON-SCRIBNER (Bull. 1, Iowa Geological Survey), pp. 1–525, woodcuts in text 220, 1901.—This is an elaborate scientific discussion of the grasses of the state by botanists, though published as the first of the Bulletins of the Geological Survey, which is authorized to publish on subjects "of economic interest relating to the Natural History of the State." It is a paper one would naturally look for among the agricultural reports. The illustrations present numerous histological details as well as representations of the form and modes of growth of the plants.

5. *The Birds of North and Middle America;* by ROBERT RIDGEWAY. Part I, Family Fringillidæ—the Finches. Pp. xxx, 715; with 20 plates. Washington, 1901 (Bulletin No. 50, U. S. Nat. Museum, Smithsonian Institution).—The comprehensive character of this valuable work will be seen from the statement in the preface that it is intended to describe in it "every species and subspecies, or definable form, of bird found on the continent of North America, from the arctic districts to the eastern end of the Isthmus of Panama, together with those of the West Indies and other islands of the Caribbean Sea (except Trinidad and Tobago) and the Galapago Archipelago; introduced and naturalized species being included as well as accidental or casual visitors."

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Smithsonian Institution; Documents Relative to its Origin and History*, 1835–1899, compiled and edited by WILLIAM JONES RHEES, in two volumes, vol. ii, 1887–1899, pp. xvi, 1045–1983.—This second volume of the valuable compilation of Smithsonian Documents, noticed in the December number of this Journal (p. 473), has recently been issued and completes this important work.

2. *Scientia.*—This valuable series, published in Paris by G. Carre and C. Naud under the above name, has received the following additions:

Production et emploi des Courants alternatifs; par L. Barbillion. (Phys.-Mathèmatique, No. 11.) Pp. 103, 1901.

La Sèrie de Taylor et son prolongement analytique; par J. Hadamard. (Phys.-Mathèmatique, No. 12.) Pp. 102, 1901.

Knowledge Diary and Scientific Hand-book for 1902. Pp. 112. London, 1901. Issued in conjunction with "Knowledge" (Knowledge Office, 326 High Holborn). The varied scope of this volume will be seen from the following statement of its contents. It contains original descriptive articles on the observation of comets and meteors; how to use an equatorial telescope; the microscope and its uses; aids to field botany; hints on meteorology; and monthly astronomical ephemeris. Also the paths of the principal planets for the year, illustrated with charts; astronomical notes and tables, with an account of the celestial phenomena of the year; and twelve star maps showing the night sky for every month in the year, with full descriptive account of the visible constellations and principal stars; a calendar of notable scientific events; an obituary for the year.